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The *BioSulphide Process* to Treat Acid Mine Drainage and Anaconda Tailings at Caribou Mine, New Brunswick

Biomet Mining Corporation

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Minerals, Policy and Planning Division
Department of Natural Resources and Energy
Province of New Brunswick

Hon. Jeannot Volpé
Minister of Natural Resources and Energy

April, 2002

New Nouveau
Brunswick

Natural Resources and Energy
Minerals, Policy and Planning

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Biomet Mining Corporation

This report has been prepared by Biomet Mining Corporation, Richmond, British Columbia for Caribou Mine, Bathurst, New Brunswick and the Province of New Brunswick. The document has been published as received from the author. Value-added/Mineral Processing Program report received April, 2000.

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biomet

The *BioSulphide Process* to Treat AMD and Anaconda Tailings at Caribou Mine

Phase 1 Report
VAMP Project 9901

Prepared for:

Caribou Mine
Bathurst, New Brunswick

Robert Carreau
Superintendent of Environmental Services

November 1999

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Project Summary

Laboratory Scoping Study

Based on scoping level laboratory test results, the following conclusions were reached:

- Copper can be recovered selectively from AMD and tailings leachate solutions. The copper level in the treated water is <0.01 mg/L. Copper concentrate grades were low due to low copper levels in the AMD feed.
- Cadmium will precipitate with the copper.
- Zinc can be selectively recovered resulting in a treated solution containing approximately 1.0 mg/L Zn and a zinc concentrate grading 56% Zn. The zinc concentrate settles rapidly, approximately 6 cm/min., without additional flocculant.
- Hydroxide sludge can be admixed with AMD and used to remove ferric iron prior to the metals precipitation circuit. Significant copper and zinc can be leached from the sludge for subsequent recovery in the precipitation circuit.
- Iron and aluminum can be removed from solution following copper and zinc recovery using only bioreactor discharge as the alkaline source to pH 7. Manganese removal was incomplete, 4 mg/L in the treated water, using only biodischarge. Lime and/or limestone will be required to remove all of the Mn, if required.
- There was no indication that any component of the Caribou AMD or hydroxide sludge was deleterious to continuous bioreactor operation.
- Over 80% of the zinc contained in the Anaconda Pond A tailings can be extracted in a simple sulphate leach solution at 50 C, using the Caribou AMD as a sulphate and ferric iron source. Approximately 35% of the copper can be extracted under similar leaching conditions. Previous testwork indicated that other Anaconda tailings deposits at Caribou are more oxidized and the copper more readily extracted under mild sulphate leach conditions. Detailed results of the Anaconda tailings leach testing is reported under separate cover by RPC.

Draft Prefeasibility Study

A prefeasibility study was completed to evaluate the potential for commercial application of the BioSulphide Process at Caribou Mine for AMD and Anaconda tailings treatment and concurrent metal recovery. The study was based on existing laboratory data for application at Caribou and on existing BioSulphide data from pilot studies for similar applications.

Following completion of the laboratory scoping testwork, a due diligence site visit was completed in September 1999 to provide site specific information and local costing data to complete a prefeasibility study.

There were four process scenarios included in the study:

Option 1a – treatment of 700 m^3/d AMD only
Option 1b – treatment of 700 m^3/d AMD plus 70 tpd tailings/sludge
Option 2a – treatment of 2,100 m^3/d AMD only
Option 2b – treatment of 2,100 m^3/d AMD plus 210 tpd tailings/sludge

The results of the analysis can be summarized:

	($Cdn)			
	Option 1a	**Option 1b**	**Option 2a**	**Option 2b**
Purchased Equipment	911,500	911,500	1,569,750	1,569,750
Construction	1,011,545	1,011,545	1,832,893	1,832,893
Total Capital	**1,923,045**	**1,923,045**	**3,402,643**	**3,402,643**
Annual Operating Cost	391,280	982,580	822,710	2,573,615
Annual Revenue	231,775	1,199,025	732,920	3,567,875
Net Annual Revenue(Cost)	**(159,392)**	**216,317**	**(89,977)**	**994,092**
Annual Lime Savings	145,000	145,000	435,000	435,000
Annual Sludge Savings	unknown	unknown	unknown	unknown
Net Annual Profit (Cost)	**(14,392)**	**361,317**	**345,023**	**1,429,092**

Based on these results it is recommended to proceed with a mini-pilot study at site to provide confirmation of selected design criteria, pilot plant design and operating criteria and process products for downstream testing. The prefeasibility can be completed following completion of the mini-pilot testing and additional tailings leach testing.

Sommaire du projet

Étude de délimitation en laboratoire

Les résultats des essais en laboratoire sur le niveau de délimitation ont permis d'aboutir aux conclusions qui suivent.

- Il est possible de récupérer le cuivre de façon sélective des solutions de lixiviat de résidus et de drainage minier acide (DMA). La concentration de cuivre dans l'eau traitée est inférieure à 0,01 mg/L. Les teneurs en concentré de cuivre étaient basses en raison des faibles concentrations de cuivre dans l'alimentation en DMA.
- Le cadmium formera un précipité avec le cuivre.
- Le zinc sera récupéré de façon sélective, de sorte qu'on obtiendra une solution de traitement renfermant environ 1,0 mg/L de Zn et un concentré de zinc d'une teneur de 56 % de Zn. Le concentré de zinc se précipite rapidement, soit à un rythme d'environ 6 cm la minute sans floculant supplémentaire.
- Les boues d'hydroxyde peuvent être mélangées avec le DMA et servir à l'extraction du fer ferrique avant le circuit de précipitation des métaux. Des quantités prononcées de cuivre et de zinc peuvent être lixiviées des boues en vue d'une récupération subséquente dans le circuit de précipitation.
- On peut extraire le fer et l'aluminium de la solution à la suite de la récupération du cuivre et du zinc en utilisant seulement les rejets du bioréacteur comme source alcaline jusqu'à un pH de 7. L'extraction du manganèse a été incomplète : 4 mg/L étaient présents dans l'eau traitée, et ce, en utilisant seulement les biorejets. Il faudra de la chaux ou du calcaire pour enlever la totalité du Mn, au besoin.
- On n'a relevé aucune indication signalant que des boues d'hydroxyde ou des éléments du DMA de Caribou pourraient nuire au fonctionnement continu d'un bioréacteur.
- On peut extraire plus de 80 % du zinc que renferment les résidus d'Anaconda Pond A dans une simple solution de lixiviat de sulfate à 50 °C, en utilisant le DMA de Caribou comme source de sulfate et de fer ferrique. On peut extraire approximativement 35 % du cuivre dans des conditions de lixiviation semblables. Des essais antérieurs ont révélé que d'autres dépôts de résidus d'Anaconda à Caribou sont plus oxydés et qu'il est plus facile d'extraire le cuivre au moyen d'un lixiviat de sulfate léger. Le CRP fait état des résultats détaillés d'essais avec le lixiviat de résidus d'Anaconda sous pli séparé.

Étude préliminaire de faisabilité

On a réalisé une étude préliminaire de faisabilité pour évaluer les possibilités d'application commerciale du procédé BioSulphide à la mine Caribou aux fins du traitement des résidus d'Anaconda et du DMA, ainsi que de la récupération concomitante des métaux. L'étude a été basée sur des données de laboratoire existantes appliquées à la mine Caribou et sur des données existantes au sujet du procédé BioSulphide provenant d'études pilotes réalisées aux fins d'applications analogues.

Une fois les essais de délimitation en laboratoire terminés, on a effectué en septembre 1999 une visite préalable des lieux pour obtenir des renseignements précis sur les lieux et des prévisions des coûts locaux en vue de la réalisation d'une étude préliminaire de faisabilité.

L'étude envisage quatre scénarios du point de vue des procédés.

Option 1a Traitement de 700 m^3/j du DMA seulement.
Option 1b Traitement de 700 m^3/j du DMA plus 70 t/j de résidus/boues.
Option 2a Traitement de 2 100 m^3/j du DMA seulement.
Option 2b Traitement de 2 100 m^3/j du DMA plus 210 t/j de résidus/boues.

On peut résumer ainsi les résultats de l'analyse :

	(\$CAN)			
	Option 1a	**Option 1b**	**Option 2a**	**Option 2b**
Achat de matériel	911 500	911 500	1 569 750	1 569 750
Construction	1 011 545	1 011 545	1 832 893	1 832 893
Coûts d'investissement totaux	**1 923 045**	**1 923 045**	**3 402 643**	**3 402 643**
Coûts d'exploitation annuels	391 280	982 580	822,710	2 573 615
Revenus annuels	231 775	1 199 025	732,920	3 567 875
Revenu net (Coût)	**(159 392)**	**216 317**	**(89,977)**	**994 092**
Économies annuelles de chaux	145 000	145 000	435 000	435 000
Économies annuelles de boues	inc.	inc.	inc.	inc.
Bénéfice net (Coût) annuel	**(14 392)**	**361 317**	**(345 023)**	**1 429 092**

Compte tenu de ces résultats, il est recommandé qu'on effectue une mini-étude pilote sur les lieux pour obtenir une confirmation des critères de calcul retenus, de la conception de l'installation pilote et des critères de fonctionnement pertinents, ainsi que des produits obtenus aux fins d'essais ultérieurs. On pourra réaliser l'étude préliminaire de faisabilité une fois qu'on aura terminé les essais de la mini-étude pilote et les essais supplémentaires avec le lixiviat de résidus.

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Acknowledgements

The project summarized herein is a joint effort of Breakwater Resources Ltd., Caribou Mine and Biomet Mining Corporation. Contributions, both technically and financially, from the government of New Brunswick, Department of Natural Resources and Energy, VAMP program 1999, are gratefully acknowledged.

Confidentiality

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1.0 Introduction

1.1 Objective

The project objective is to determine the potential for application of the BioSulphide Process at the Caribou Mine to enhance resource recovery and concurrently treat acidic waste products for disposal.

The treatment objectives considered in developing the process alternatives were:

- Recover Cu and Zn and remove Pb from the mine water (into a Zn concentrate) to help off-set treatment costs and replace the existing lime plant. Also, this would remove these mobile metals from any process sludge and therefore allow sludge deposition with the mill tailings for long term storage, and
- Identify a method to re-treat the hydroxide sludge, overlaying the Anaconda tailings and currently discharged to the pit, to recover Cu and Zn and remove Pb for the reasons above, and
- Incorporate re-treatment of the Anaconda tailings for recovery of soluble Cu and Zn and to remove Pb, again to off-set costs and allow deposition in the tailings pond for long term storage, and
- Minimize capital and operating costs.

1.2 Scope

Following is the proposed development program for application of the BioSulphide Process at Caribou Mine. The program is divided into the following sequence:

1. Initial Review – **complete**
2. Laboratory Scoping – **complete**
    - Case 1
    - Case 2
    - Case 3
3. Site Due Diligence - **complete**
4. Prefeasibility Study (internal) – **draft complete**
5. Site Mini-Plant – **in progress**
6. Site Pilot Plant
7. Feasibility Study (independent)
8. Commercial Demonstration Plant

Overall Project Outline

Initial Review: Initial project review by Biomet to determine potential project economics. Site data provided by Caribou.

Initial Laboratory Scoping: Laboratory test program conducted at Biomet's laboratory in Vancouver using samples shipped from site. To determine basic process amenability and primary process design criteria for piloting.
Site Due Diligence: Site visit by Biomet to obtain site specific data and to review the Biosulphide application with site personnel to determine the most suitable development program.
Prefeasibility Study: Conducted by Biomet to determine the preliminary project economic return. Biomet currently uses H.A. Simons to provide independent cost estimation.
Onsite Mini-pilot: Using a laboratory mini-pilot apparatus, conduct amenability testwork at site to determine any effects of fresh sample on the process and to provide site training and biomass development for large scale piloting.
Letter of Intent: To outline the commercial terms for site piloting, engineering, construction and operation.
Site Pilot Plant: Designed, constructed and operated by Biomet to determine feasibility level design criteria.
Feasibility Study: Independent feasibility study conducted by Biomet for commercial operations.
Commercial Demonstration Plant: Designed and constructed by Biomet. Biomet is the operator, initially. Caribou retains option to purchase Biomet's interest after 10 years.

1.3 Review of Process Alternatives

1.3.1 BioSulphide Process Background

A summary description of the BioSulphide Process is included in Appendix 1, along with a copy of the process patent.

1.3.2 Project Background and Initial Review of Process Alternatives

Based on a site visit and two reports provided by Caribou (RPC and Lorax), a preliminary review of process alternatives to treat acidic mine seepage as well as the Anaconda tailings using the BioSulphide Process was completed. The underlying objective is to treat the Anaconda tailings, including the overlaying sludge, to remove the mobile metals such as Cu, Zn and Pb so that the treated tailings can be deposited with mill tailings in the tailings pond. Co-deposition with lime hydroxide sludge is not a viable option by local regulation. Back-filling the underground mine is not a viable alternative based on discussions with site personnel.

Based on the probable recoverable metal in the Anaconda tailings, it is unlikely that a stand alone BioSulphide plant could be justified. Therefore, the alternatives included treatment plants that could be utilized long term to treat acidic mine drainage, thus eliminating lime treatment and the associated reagent and sludge storage costs. The annual savings in lime consumption was estimated by Caribou Mine personnel at $Cdn145,000 annually. There is no credit assumed for reduction in sludge storage, although this should be considered in more detailed valuations.

A process flowsheet is included for each of the alternatives. The process alternatives were based on limited data and should be considered preliminary for discussion purposes only. All process information was developed by Biomet and the preliminary cost estimates were conducted in-house, based on previous estimates provided by HA Simons. It was the objective of Biomet to determine if there is any potential for application of the BioSulphide Process at Caribou Mine.

Case 1 – Acid Mine Drainage Treatment

Case 1 alternative is simply replacing the lime plant with a BioSulphide plant for long term acid water treatment. In this case, a zinc concentrate is produced (approximately 336,000 lb ZnS annually), also containing copper, lead and any cadmium in the drainage. Diesel fuel is used as the nutrient. The BioSulphide product solution is then treated with limestone for iron, aluminum and manganese removal into a high density carbonate sludge for disposal. A small amount of NaHS is produced as a co-product (0.77 tonnes per day) due to excess H_2S produced for process balance.

The result is a process showing a net cost annually. If the lime savings is applied, there is **a net savings annually and a reduction in sludge volume** compared with the current treatment plant. It is unlikely that the incremental capital can be justified based on these savings alone.

> *Assumptions to confirm: sulphate reduction rate, fuel utilization, consumable costs, concentrate quality.*
> *Data required: AMD – Fe^{2+}/Fe^{3+} ratio, $SO_4^{2=}$, acidity, cobalt.*

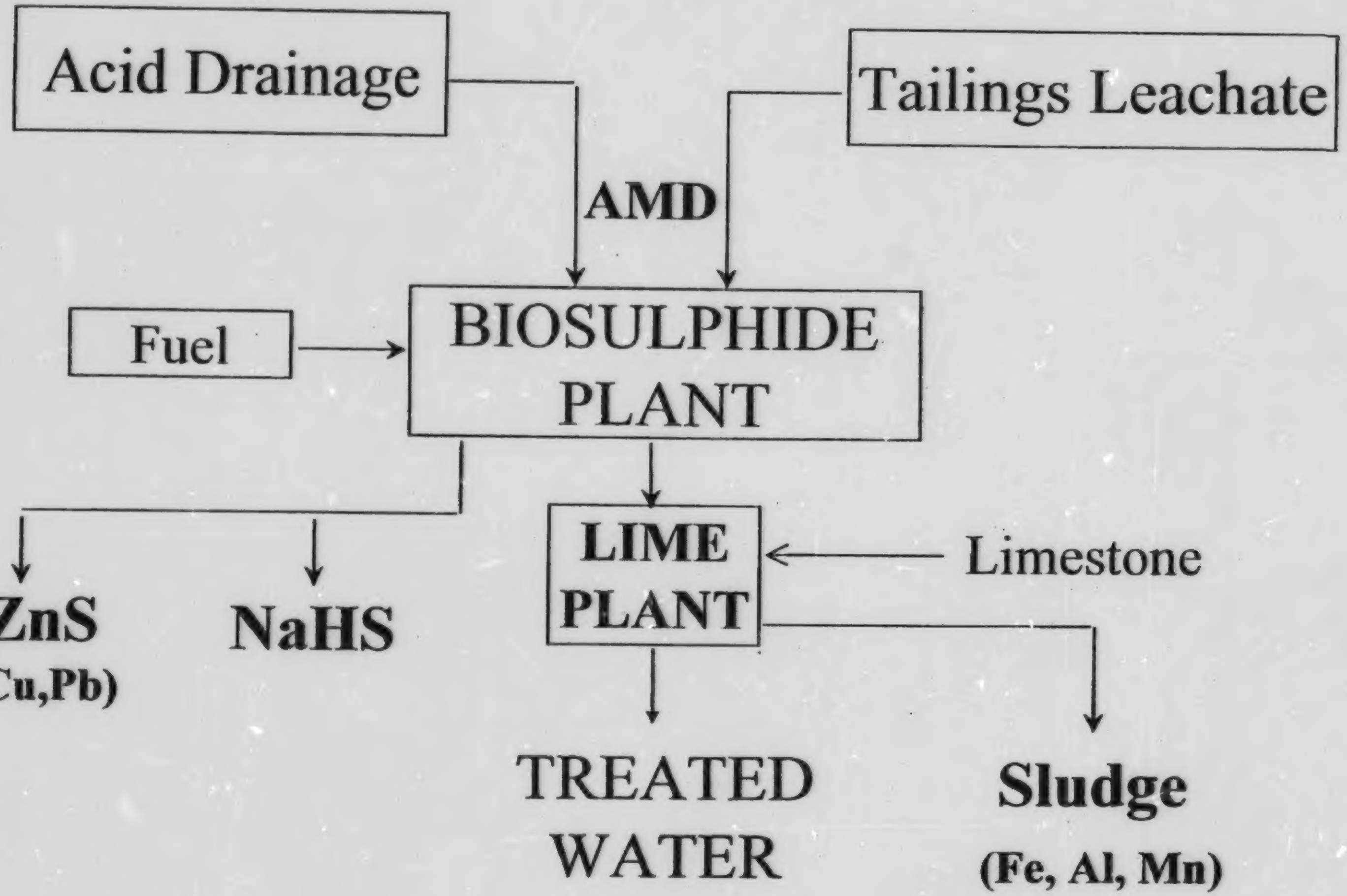
Case 2 – Add Hydroxide Sludge to Case 1 Flowsheet

Essentially the same flowsheet as Case 1 except the limestone addition is replaced with hydroxide sludge, which increases the recovered ZnS annually, due to contained $ZnSO_4$ in the sludge, and eliminates the limestone costs.

The result is a process with a break-even operating cost, showing a slight profit annually. When the lime savings credit is applied **the net revenue is slightly higher than Case 1 on an annual basis and sludge volume is reduced.** This alternative does not consume sufficient hydroxide sludge to make a significant impact on the sludge disposal problem, however, the process economics are slightly better than Case 1.

> *Assumptions to confirm: as above*

Caribou Mine - Case 1
AMD Treatment



Acid Drainage

Tailings Leachate

AMD

Fuel

BIOSULPHIDE PLANT

LIME PLANT

Limestone

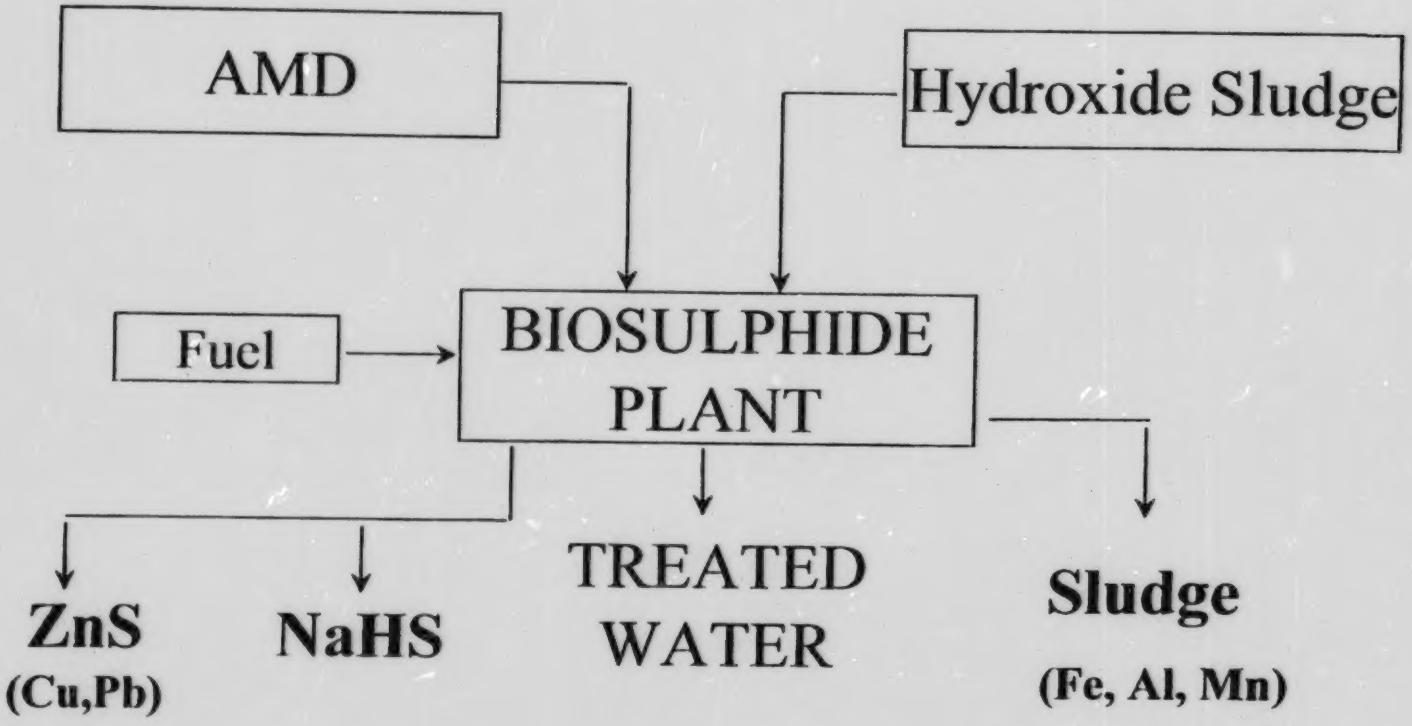
ZnS
(Cu,Pb)

NaHS

TREATED WATER

Sludge
(Fe, Al, Mn)

Caribou Mine - Case 2
AMD plus Hydroxide Sludge



AMD

Hydroxide Sludge

Fuel

BIOSULPHIDE PLANT

ZnS
(Cu,Pb)

NaHS

TREATED WATER

Sludge
(Fe, Al, Mn)

Data required: as above plus NNP and metal content of the hydroxide sludge

Case 3 – Integrated Processing of AMD and Anaconda Tailings/Sludge

Case 3 is significantly more complex than either Case 1 or Case 2, but has the potential to contribute more to capital repayment if the metal recovery from the tailings is successful. The process requires dissolution of the Anaconda tailings/sludge using both AMD from the property and locally purchased sulphuric acid. The leached tailings are washed for disposal and the resultant leachate is then processed using the BioSulphide Process to recover separate copper and zinc concentrates. We have assumed that the Anaconda tailings and sludge would be re-treated over 6 years, to minimize capital. This will be confirmed in the prefeasibility study.

The overlying sludge on the Anaconda tailings contains significant zinc values which can be recovered in the process. However, more sulphate must be reduced due to the increased sulphate from the sludge and sulphuric acid. This results in a significant production of co-product NaHS, for which a local market probably exists at the pricing used in preliminary cost and revenue estimates.

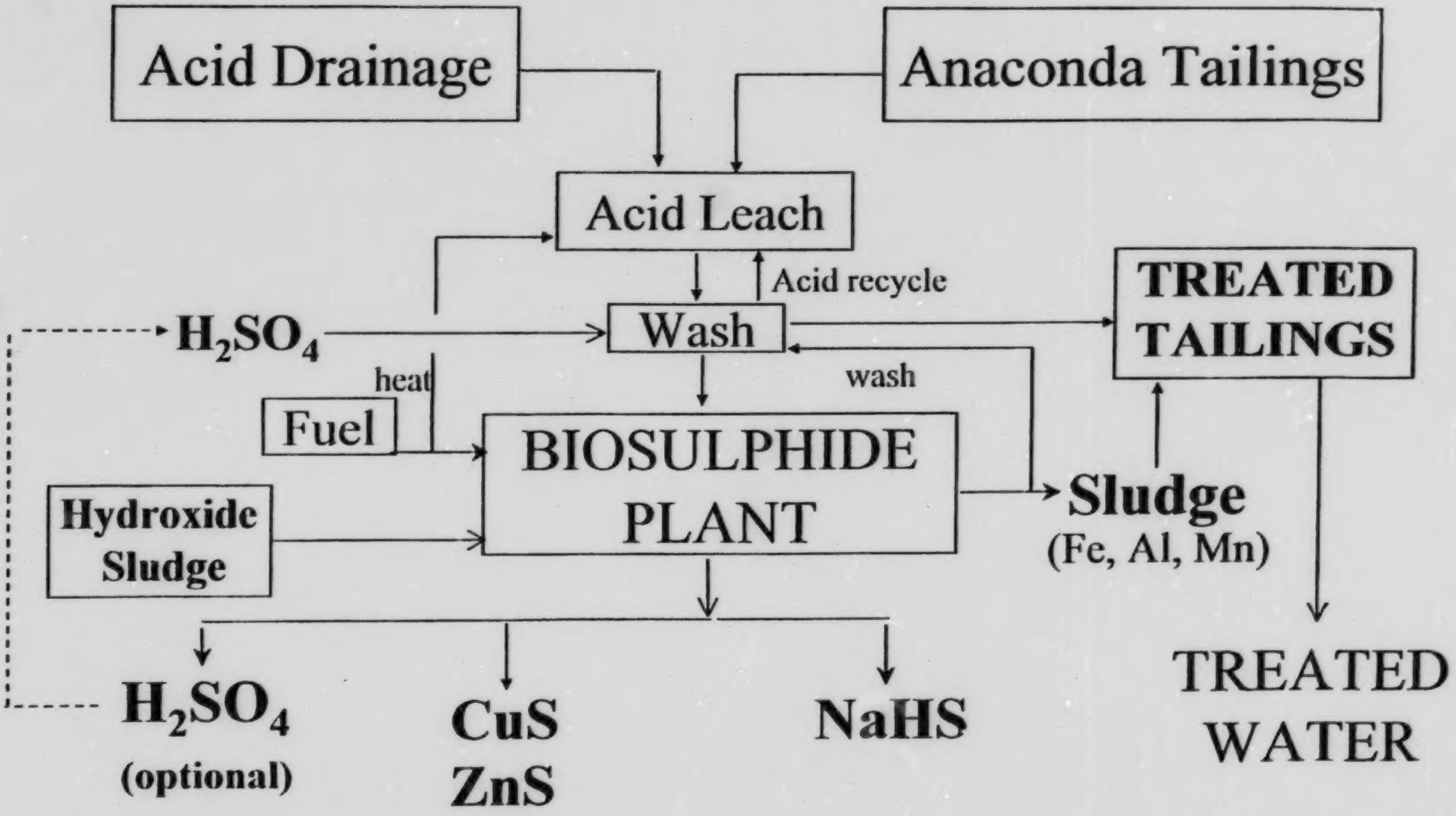
The tailings leach in warm acid (waste heat from the BioSulphide Process) is based on testwork previously conducted at RPC. The acid consumption appears high, however the data was used as presented. It is likely that the Zn extraction during tailings leaching can be improved using a small amount of ferric iron, which might be supplied by the existing acid drainage. We have used 80% Cu extraction and only 40% Zn extraction from the tailings.The data reviewed suggests that **bioleaching of the tailings is not warranted.** The resultant leached tailings should be acceptable for deposition in the tailings pond.

The data indicates that there is significant cobalt levels in the Anaconda tailings and hydroxide sludge. This has not been included as a potential revenue but represents a significant up side to the economics. In addition, it is possible to recycle sulphuric acid from excess H_2S, which might improve the process economics, depending on actual reagent costs for sulphuric acid and soda ash as well as local NaHS markets.

The results show a net revenue annually before lime savings are applied, for the first 6 years during which the Anaconda Tailings are leached. In addition, the process proposed results in the elimination of the Anaconda tailings/sludge as a liability. Once the tailings re-treatment is completed, the BioSulphide plant would have excess capacity to treat lime hydroxide sludge currently stored in the abandoned pit, if sufficient metal values and local regulation so warrant. Capital payback must be confirmed with additional testwork and economic analysis.

Assumptions to confirm: as above plus recoverable tailings quantities and grades, NaHS local pricing and market, sulphuric acid recycle from H_2S, overall heat balance.

Caribou Mine - Case 3
Integrated Processing


Acid Drainage
Anaconda Tailings
Acid Leach
Acid recycle
H_2SO_4
Wash
TREATED TAILINGS
heat
wash
Fuel
BIOSULPHIDE PLANT
Hydroxide Sludge
Sludge (Fe, Al, Mn)
H_2SO_4 (optional)
CuS ZnS
NaHS
TREATED WATER

Data required: as above plus tailings/sludge NNP, leaching curves for Cu, Zn, Pb, Cd, Fe, Al and Co under various conditions of density, acid drainage concentration, Fe^{3+} concentration, temperature, free acid and retention time.

Note on Capital Cost

Capital costs have not been estimated due to the preliminary nature of the flowsheet development and absence of information on existing equipment that could be utilized. However, the major capital item is the bioreactor(s) and based on the preliminary sizing for Case 3, the capital cost will be approximately $US 2-3 million, depending on available equipment and infrastructure at site. Case 1 and 2 would probably cost under $US 1 million.

2.0 Project Methodology

2.1 Laboratory Scoping

Objective: To provide confirmation operating data and process design criteria for prefeasibility purposes and determine overall process amenability.

Case 1: Treatment of Acidic Mine Drainage

Using water sample from site the objective is to operate a continuous laboratory system to define bioreactor operating criteria and to conduct precipitation scoping studies for zinc recovery. The product from the BioSulphide processing is then treated with lime and/or limestone to determine reagent requirements and final sludge quality for Fe, Al and Mn removal.

The apparatus includes a continuous single-stage bioreactor and two-stage precipitation circuit with process ancillaries and automatic controls. Metals of interest include Zn, Cu, Cd, Co, Pb, Fe, Al and Mn. Continuous sampling of bioreactor operating parameters and product solution.

Case 2: Treatment of AMD including sludge

As above except lime/limestone is replaced with hydroxide sludge from site. Additional assays include NNP determination for sludge sample.

Case 3: Treatment of AMD/Anaconda Tailings re-treatment

Laboratory scoping testwork on Anaconda Tailings and the overlaying sludge to provide confirmatory design criteria and reagent requirements for inclusion into Case 3 flowsheet evaluation. Standard batch laboratory tests to determine leachability curves for Cu, Zn, Pb, Cd, Co, Fe, Al with respect to slurry density, AMD addition rate, free acid concentration, temperature, Fe^{3+} concentration and temperature.

Detailed description of the laboratory procedures are included in Section 3 of the Laboratory Scoping Report, Appendix 2.

An independent report of the Anaconda Tailings leach testwork, from RPC in Fredericton, including details of test procedures, is included in Appendix 3.

Sample Requirements:

Site AMD – 100 litres in sealed plastic containers.
Hydroxide Sludge – 10 litres in a sealed plastic container.

Anaconda Tailings – approx. 50 kg (dry wt.), fresh wet sample
Overlaying Sludge – approx. 50 kg (dry wt.), fresh wet sample

Report:

Summary report of all test results provided by Biomet.

Decision Point:

The results of the laboratory scoping test program described above will provide sufficient information to revise process estimates conducted during the initial review to determine if additional development work is warranted. Based on positive results, the project could proceed to the next step – Site Due Diligence and Prefeasibility Study

2.2 Site Due Diligence

The site due diligence is required to obtain more accurate data regarding capital and operating costs, including retro-fits to existing equipment, to complete the prefeasibility study. The due diligence visit will include meetings with regulatory authorities to obtain compliance targets for the pilot plant and commercial operation.

2.3 Prefeasibility Study

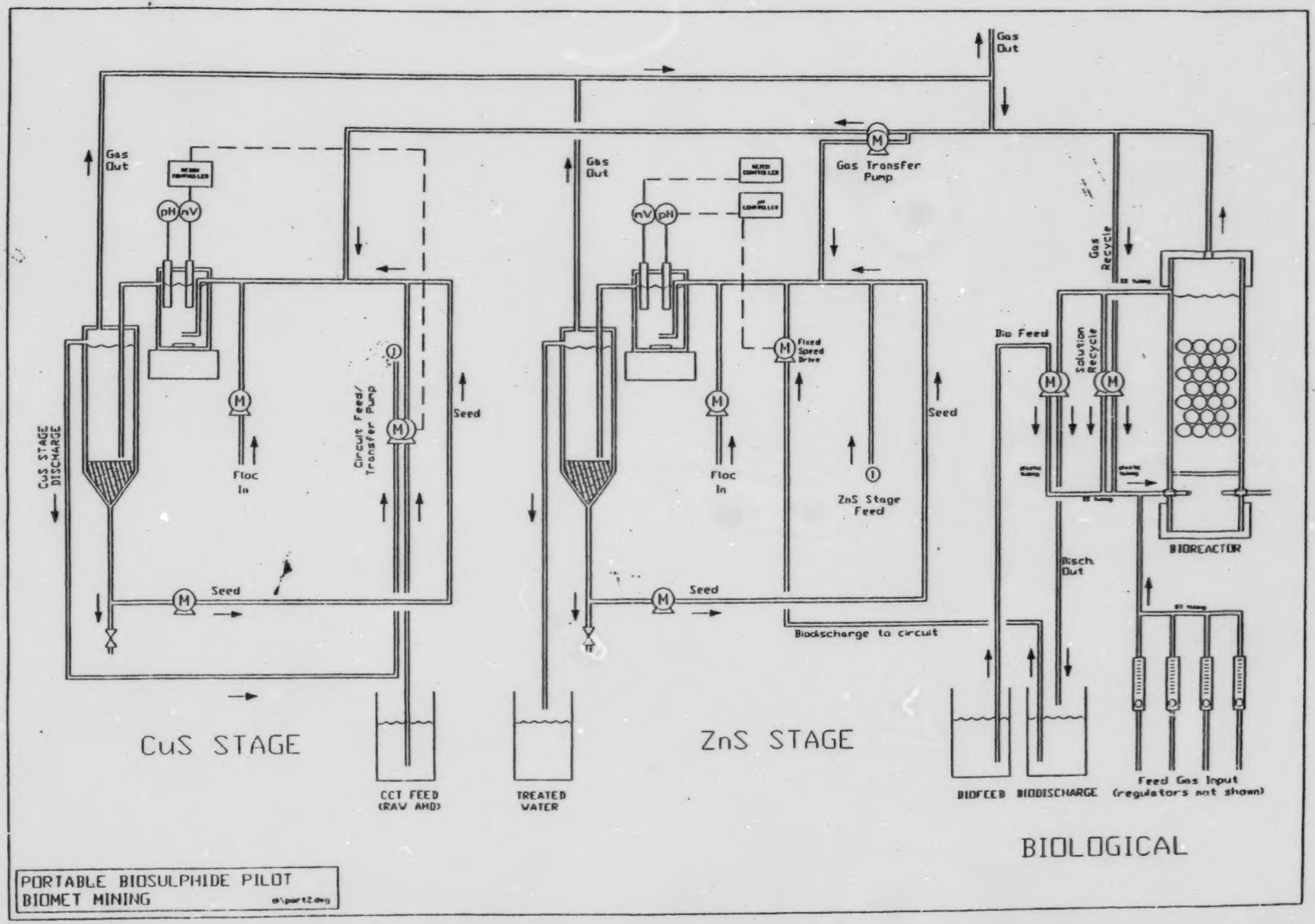
A standard prefeasibiltiy study will be completed by Biomet in-house using engineering criteria provided by HA Simons on similar projects. The accuracy of estimates will be +/- 30%.

2.4 Mini-pilot Plant

If the results of the prefeasibility are positive then a mini-pilot plant will be supplied by Biomet for operation at site or at RPC, depending on availability of operating personnel. The objectives of the mini-plant include:

- Confirmation of process operating criteria using fresh feed water and tailings samples
- Confirmation of process design criteria to complete the prefeasibility study
- Site personnel training
- Site biomass development for future pilot operations

A copy of the circuit flowsheet is attached. The circuit is complete including a copper and zinc stage reactor/clarifier, integrated bioreactor and bioclarifier, flocculant system, reagents, pumps, mixers, transfer lines, gas manifold, instrumentation, wiring, reagents


Gas Out
Gas Out
Gas Out
Gas Transfer Pump
Gas Recycle
pH
mV
Circuit Feed/ Transfer Pump
Floc In
Seed
Seed
CuS STAGE DISCHARGE
Fixed Speed Drive
ZnS Stage Feed
Floc In
Seed
Seed
Biodischarge to circuit
Bio Feed
Solution Recycle
Bisch Out
BIOREACTOR
CCT FEED (RAW AMD)
TREATED WATER
BIOFEED
BIODISCHARGE
Feed Gas Input (regulators not shown)
CuS STAGE
ZnS STAGE
BIOLOGICAL
PORTABLE BIOSULPHIDE PILOT
BIOMET MINING
e\part2.dwg

and biomass. Not supplied are feed and product pails, bottled gases (N2, H2, CO, CO_2) and the feed pretreatment mix tanks and filter (for tailings and hydroxide sludge leaching). The tailings leach work can be done on a batch basis with existing laboratory equipment at Caribou to prepare the feed solution for BioSulphide processing. The mini-pilot circuit requires 120VAC power supply (15 A) and a vent to a fume hood for safety considerations.

Biomet will provide the detailed design, fabrication, equipment procurement and initial circuit testing in Vancouver. The circuit will be shipped separate from the biomass, which has been developed using Caribou water. Biomet will provide a pilot engineer to re-assemble and start up the circuit at Caribou. At the same time, our engineer will provide site training for circuit operation and any specialized assay/sampling procedures required, estimated at 2 weeks on site.

The mini-pilot circuit is started in stages – first the bioreactor, using a synthetic AMD feed source. Synthetic feed is used to develop the biomass and sulphate reduction rate to provide sufficient H_2S and biogenic carbonate to operate the copper and zinc precipitation circuit on an integrated basis. The integrated circuit is operated using fresh Caribou AMD, Anaconda tailings and hydroxide sludge samples (Case 3 flowsheet). Continuous feed rates to the BiSulphide circuit will be 1-2 litres per day of leachate solution containing acid and metals.

Details of laboratory infrastructure, supplies and analytical procedures to operate the mini-pilot circuit are provided under separate cover.

The optimization of the AMD/Anaconda tailings leach stage as well as the addition of hydroxide sludge for iron precipitation can be conducted independent from the integrated BioSulphide circuit, by others.

3.0 Results and Discussion

3.1 Laboratory Scoping

The results and discussion of the Laboratory Scoping work are included under separate cover "Laboratory Scoping Testwork Final Report", dated August 1999, and included in Appendix 2.

The leaching testwork conducted independently by RPC of Fredericton is also included under separate cover, Appendix 3.

3.2 Draft Prefeasibility Study

The Draft Prefeasibility Study, dated November 1999, is included under separate cover in Appendix 4. Completion of the prefeasibility study is pending results from the mini-pilot plant testwork as well as additional tailings leach testwork scheduled at RPC.

4.0 Conclusions and Recommendations

4.1 Laboratory Scoping Study

Conclusions

- Copper can be recovered selectively from AMD and leach solutions. The copper level in the treated water is <0.01 mg/L. Copper concentrate grades were low due to low levels in the AMD feed. Additional copper precipitation work will be required to include tailings leachate solution with higher copper levels
- Zinc can be selectively recovered resulting in a treated solution containing approximately 1.0 mg/L Zn and a zinc concentrate grading 56% Zn. The zinc concentrate settles rapidly, approximately 6 cm/min., without additional flocculant.
- Hydroxide sludge can be used to remove ferric iron prior to the metals precipitation circuit and significant copper and zinc can be leached from the sludge for subsequent recovery in the precipitation circuit.
- Iron and aluminum can be removed from solution following copper and zinc recovery using only bioreactor discharge as the alkaline source to pH 7. Manganese removal was incomplete, 5 mg/L in the treated water, using only biodischarge. Lime and/or limestone will be required to further reduce Mn levels in the treated water.
- There was no indication that any component of the Caribou AMD or hydroxide sludge was deleterious to continuous bioreactor operation.
- Over 80% of the zinc contained in the Anaconda Pond A tailings can be extracted in a simple sulphate leach solution at 50 C, using the Caribou AMD as a sulphate and ferric iron source. Copper extraction was 32-39%, depending on ferric iron concentration.

Recommendations

The results of the laboratory scoping testwork summarized herein show that continued development of the project is warranted. It is recommended that the Site Due Diligence and Prefeasibility Study stages of the overall proposed programme are initiated, using Case 3 flowsheet alternative. Also, it is recommended that a mini-pilot circuit is operated at site to better define the process variables in continuous steady state, prior to site piloting, and to integrate Anaconda tailings leaching into the flowsheet (Case 3).

Comparative leachability tests and humidity cell testing should be conducted on the mill tailings, Anaconda tailings and the combined residue from BioSulphide testing to determine relative metal mobility and potential toxicity.

4.2 Draft Prefeasibility Study

Conclusions

Based on the laboratory data available and the analysis provided in this study, the salient conclusions are:

- The process Option 2b, treatment of 2,100 m^3/d AMD and concurrent re-treatment of 210 tonnes per day Anaconda Tailings, results in a project with a capital payback of approximately 3 years, re-treatment of all of the Anaconda Tailings and overlying sludge in slightly more than 5 years, and a treatment plant that is moderately over-sized for ongoing treatment of 2,100 m^3 per day AMD.
- Utilization of the BioSulphide Process would provide a long term treatment alternative for AMD neutralization that would show a slight profit annually, at current metal prices and including a credit for lime savings. The ongoing sludge produced would have copper, zinc, lead and cadmium removed and can probably be stored in the tailings pond, reducing sludge liability long term.
- The total capital cost, for new equipment and independent contractors for construction was estimated at $Cdn 3.4 million for Option 2b.

Financial Analysis

The estimates provide for Options 2a and 2b indicate that there is positive project economics in the short term to reclaim and re-treat Anaconda Tailings for metal recovery and tailings disposal and in the long term for ongoing AMD treatment.

The project is particularly sensitive to fuel costs, which is directly related to the overall hydrogen utilization from the partial oxidation burner and in the bioreactor. The overall hydrogen utilization value of 60% is reasonable based on current burner and pilot information. Also, the project is very sensitive to diesel fuel price.

The metal pricing and NSR estimates for the concentrate products used in the operating cost/revenue estimates are reasonable based on current markets. The project is sensitive to metal pricing and concentrate grade and related smelter terms.

Upside Potential

There is significant upside potential in the project if oxidized tailings are included in the leach circuit estimates. The data provided by RPC, Appendix 1, suggests that a significant portion of the Anaconda Tailings have been oxidized, which will result in an increase in the recoverable metals, thus an increase in revenues, particularly from copper.

There is significant cobalt content in the hydroxide sludge overlaying the tailings. It might be possible to selectively recover this cobalt to a saleable end product, increasing revenues.

The neutralizing potential and residual sulphate content of the hydroxide sludge has not been incorporated in the analysis. There is potential for savings in limestone and gypsum once confirmatory data on sludge quality is available.

Recommendations

Based on the results of the laboratory work todate and the results of the prefeasibility estimates it is recommended that:

- A mini-pilot plant is operated at site to confirm the BioSulphide operating criteria, to assist with pilot scale design and provide sufficient sample of concentrate and leach residue product for downstream process studies.
- Additional leaching studies are completed to incorporate areas of the stored tailings where advanced oxidation is evident and areas including overlaying sludge, to provide a better estimate of overall metallurgical balance and iron deportment.
- Comparative stability testing is conducted on the Anaconda tailings, acid leached tailings and existing mill tailings.
- Confirmation of the AMD flow and grade for the 2,100 m^3/d flowrate.

APPENDICES

Appendix 1 – BioSulphide Process Description

Appendix 2 – Laboratory Scoping Testwork, Final Report

Appendix 3 – RPC Report

Appendix 4 – Draft Prefeasibility Study

Appendix 1

BioSulphide Process Description

2.0 BIOSULPHIDE PROCESS BACKGROUND

The BIOSULPHIDE PROCESS is an integrated chemical-biological process designed to treat metal-contaminated, sulphate-rich, waste streams. The process has been developed to solve the increasing problem of treatment and disposal of solutions, gases and waste streams that contain heavy metals and sulphate in acidic waste streams. The BIOSULPHIDE PROCESS was developed with the objective of treating these waste streams with concurrent recovery of saleable metal sulphides and sulphide based co-products (eg. NaHS).

Alternative processes available to treat these and related wastes include lime precipitation, lime scrubbing, ion exchange and biosorption, conventional sulphate reduction, and wetlands. In many applications, all of these alternatives encounter technical and/or economic limitations.

2.1 Process Description

The objective in the development of the BIOSULPHIDE PROCESS was to provide a cost effective process to treat acidic sulphate-rich waste streams, that could be easily engineered and operated, using known chemical and biological process steps. The process also needed to produce a saleable grade metal sulphide product and a treated effluent that could be discharged directly to the environment. It was important that the process could be readily integrated into existing operations, without specialized personnel or infrastructure.

The BIOSULPHIDE PROCESS integrates a biological phase and a chemical phase to treat waste water streams to discharge quality and maximum metals recovery. *Essentially, it is a chemical treatment process that uses inexpensive biologically-generated reagents.* The entire stream passes through a chemical treatment stage where the pH is adjusted, using biologically generated alkalinity, and biogenic hydrogen sulphide gas (H_2S) is introduced to selectively precipitate metals from solution as sulphides. The sulphide concentrate(s) are recovered in a dedicated clarifier(s), using a high recirculating load for precipitate seeding and effective flocculation, followed by filtration for final concentrate dewatering.

A predetermined portion of the resultant 'clean' sulphate stream is fed to an anaerobic biological reactor where sulphate is biologically reduced to sulphide (H_2S). The fraction of solution to be treated biologically is normally controlled by the amount of H_2S required for sufficient metal removal. However, a larger portion might be treated if excess alkalinity and/or H_2S is desired for water treatment purposes and/or the production of saleable sulphide-based co-products, such as NaHS, depending on local markets.

The BIOSULPHIDE PROCESS utilizes a mixed anaerobic biological culture to reduce sulphate species already present in the waste water to soluble hydrogen sulphide with the simultaneous production of alkalinity, in the form of carbonate, for pH adjustment. The hydrogen sulphide is stripped into the gas phase and recycled to the chemical treatment step where dissolved metals are selectively precipitated as high grade metal sulphides which can be sold or recycled. Biologically generated alkalinity is also recycled to the chemical treatment step for pH control during selective precipitation. It is important to note that in most cases only a fraction of the total waste sulphate requires treatment to provide hydrogen sulphide sufficient for complete metal removal and pH control. The primary reactions are summarized below:

Chemical Pretreatment:

$M^{2+} + S^{2-} \rightarrow MS$ {where M^{2+} represents a 2+ metal ion}

Biological Reduction:

SO_4^{2-} + Nutrients + $H_2O \rightarrow H_2S + HCO^{3-}$

During the process biomass is continually created. Several nutrient sources have been pilot tested (eg. coal, wood, natural gas combustion products, sewage sludge, glycol and ethanol). For commercial applications, the nutrient source will likely be limited to the combustion products of natural gas, propane or diesel fuel due to the simplicity of operation, high efficiency of nutrient utilization, and because this method provides a heat source for optimum biological activity. In all cases examined to date, excess heat is generated.

The chemical stage retention time is dependent on the number of stages, H_2S concentration in the circulating strip gas, reactor type, clarifier circulating load, and product purity criteria. The chemical stage is typically less than 1 hour total retention time. The biological retention time varies with feed grade and temperature but is typically 20-40 hours.

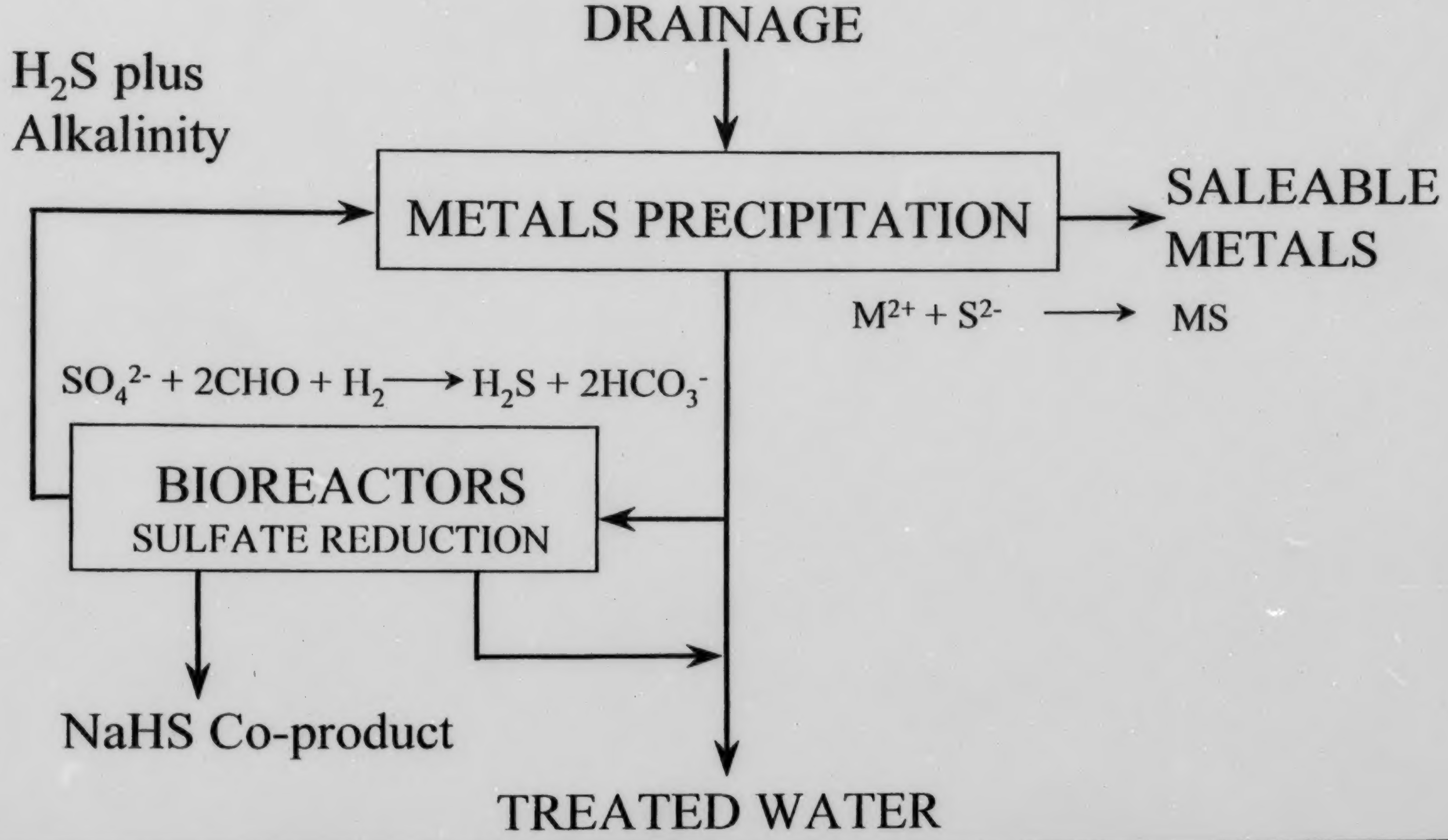
The BIOSULPHIDE PROCESS is patented. A copy of the patent is included in Appendix 1. A general process schematic is shown in Figure 1.

2.2 Applications

The BIOSULPHIDE PROCESS can be applied in most cases where acidic sulphate-rich waste water contains dissolved base metals for recovery. Typical examples of acid mine drainage (AMD) or acid rock drainage (ARD) include open pit and mine waste dump drainage, tailings pond effluents, dump leach bleed streams, refinery/smelter waste streams and naturally occurring acid rock drainage. Appendix 2 details the scope of the mine drainage problem in North America. A Federally-appointed program called MEND (Mine Environment Neutral Drainage) estimated that "the acidic drainage liability in Canada ranges from $2 billion to $5 billion", perhaps prompting the Financial Post to state that "acid drainage at existing mine operations in Canada is considered to the most serious environmental threat" (see Appendix 2).

Biosulphide Process

Generalized Schematic - Figure 1



DRAINAGE

H_2S plus
Alkalinity

METALS PRECIPITATION

SALEABLE
METALS

$M^{2+} + S^{2-} \longrightarrow MS$

$SO_4^{2-} + 2CHO + H_2 \longrightarrow H_2S + 2HCO_3^-$

BIOREACTORS
SULFATE REDUCTION

NaHS Co-product

TREATED WATER

In the U.S. in 1993 there were 58 mine sites on the EPA's National Priorities List, and the less severe problems in only nine states totaled an estimated remediation cost of over $US 4 billion. In total, the U.S. Bureau of Mines estimated that mines and mine waste "adversely affect over 12,000 miles of rivers and streams, and over 100,000 acres of lakes and reservoirs in the U.S."

Initially, the focus will be to build commercial plants at existing and/or abandoned operations where the flow and quality of the drainage are well documented for design purposes and the infrastructure is established. In the longer term, the objective is to treat more naturally occurring acid water as there are abundant sites available for treatment.

2.3 Costs

The operating cost of a BIOSULPHIDE plant will include labour, nutrients/fuel, reagents and power. The most significant consumable will be the nutrient/fuel cost, which will be directly related to the sulphate content of the waste stream, the treatment objective, and the metal content. In all cases examined so far, the heating requirement is only a fraction of the fuel required to produce sufficient nutrient for water treatment and therefore there is no additional consumable cost for heating, even in winter conditions. Reagent consumption is related to the quantity of sulphate reduced and is typically a small fraction of the nutrient cost. Power costs are minimized as the bioreactors are a simple flow-through design which limits primary power consumption to solution pumping, small clarifier drives, fans and compressors, vacuum pumps and reagent systems. Operating labour costs will be highly site specific but will generally be limited to 1 operator per shift plus 1 maintenance mechanic on a day shift basis.

Capital costs are dependent on waste water solution flow rates, metal content, and the treatment objectives. Typical commercial scale capital costs will range between US$ 3-5 million (ref. H.A. Simons). A capital cost would be derived for each site based on the flowsheet required to meet the solution treatment objectives.

2.4 Revenue Sources

The primary revenue source is the sale of base metal sulphide concentrates, including copper, zinc, cobalt and nickel. There are other revenue sources, which include the sale of sulphur based co-products, for example NaHS and elemental sulphur, from any excess H_2S produced. In addition, at many sites there is potential to charge a treatment fee to the property owner for waste water treatment and in some cases there is potential to sell treated water for industrial re-use.

2.5 Competing Technology and Competitive Advantage

Alternative processes available to treat acidic metal laden waste water include lime precipitation, lime scrubbing, ion exchange and biosorption, reverse osmosis, conventional sulphate reduction and wetlands. In most applications, these treatment alternatives encounter technical and/or economic limitations.

For example, lime treatment, the most commonly used method for the treatment of acidic sulphate solutions, produces large volumes of relatively unstable sludge which might be considered hazardous waste in some cases, and requires large lined containment areas due to possible re-mobilization of the precipitated metals. In addition, the cost of lime in many geographic locations is high, due to transportation costs. Finally, the "treated" water from lime plants often does not meet discharge quality limits without some secondary treatment step prior to discharge. Lime treatment does not offer any potential revenue sources from the sale of metals or other saleable co-products.

Solvent extraction/electrowinning (SX/EW) is a common process for the recovery of copper from acid solutions. This is a highly competitive process for large scale copper operations and has the advantage of producing a copper metal product. However, to date SX/EW has not been commercially successful in the production of zinc or nickel from complex acid sulphate solutions. The SX/EW process does not produce effluent quality discharge and would require a secondary treatment step, such as the BIOSULPHIDE PROCESS, to clean effluents before discharge. In addition, SX/EW is more capital intensive and requires large power input which is expensive in remote locations. It was not the intent to find a replacement for SX/EW for large scale copper operations but to provide an alternative for smaller scale operations for metal recovery as well as a final treatment step to augment larger SX/EW based operations and smelters/refineries.

To the knowledge of BIOMET, there are no commercially competitive operations using related technology for metal recovery. Biological sulphate reduction is a well researched and practiced biotechnology, generally used in passive natural environments for the removal of low level metal contamination and weak acid neutralization. There is one company, PAQUES, based in the Netherlands, that provides engineering services and reactor design/supply for several waste treatment applications employing various biotechnologies, including sulphate reduction. PAQUES plants are highly specialized and are limited in economic application due to complex reactor design and high cost nutrient sources.

BIOMET has unique competitive advantages in the application of biological sulphate reduction for the following reasons:

- the patent is general in description to cover most applications of interest to BIOMET
- BIOMET has developed and patented a process using low cost gaseous nutrients
- combustion of nutrient gases provides excess heat for bioreactor heating at no additional operating cost
- proven use of biologically-generated alkalinity in pH control and selective metals precipitation
- BIOMET has proven experience in the design and use of low cost, efficient reactors
- proven experience in production of saleable grade sulphide concentrates using H_2S selective precipitation and conventional clarification equipment
- BIOMET has proven scale-up engineering expertise in this process and related biotechnologies

- the principals of BIOMET are recognized internationally in biotechnology and waste water treatment and can therefore identify, evaluate and consolidate treatment opportunities

2.6 Liabilities

It is the objective of BIOMET to remain at arms length to the land ownership where metal contaminated acid drainage is encountered. BIOMET will not accept any long term liability to treat water to discharge quality or mitigation in perpetuity. BIOMET will enter into service agreements for the treatment and recovery of base metals from contaminated waters as well as water treatment fee structures where applicable. BIOMET will be responsible only for the water quality and products from the BIOSULPHIDE PROCESS plant, as well as the health and safety of it's employees.

2.7 Public Relations Benefits

There are significant public relations benefits to the use of the BIOSULPHIDE PROCESS. The process offers a long term mitigation alternative for acid rock drainage as well as more complete metal recovery overall and improved resource utilization. The BIOSULPHIDE PROCESS is a responsible waste management alternative utilizing a simple, low risk biological process. The final products from the process include:

- treated water
- metals recovered for recycle
- minimum waste sludge for disposal
- valuable co-products for industrial recycle

As a result of the positive public relations of employing the BIOSULPHIDE PROCESS, preliminary indications are that permitting for commercial operation would not require any special review and that the operation would receive favourable operating tax incentives.

US005587079A

United States Patent [19]

Rowley et al.

[11] **Patent Number: 5,587,079**

[45] **Date of Patent: Dec. 24, 1996**

[54] **PROCESS FOR TREATING SOLUTIONS CONTAINING SULFATE AND METAL IONS.**

[76] Inventors: **Michael V. Rowley; Douglas D. Warkentin**, both of 930 West 49th Avenue, Vancouver, B.C., V5Z 2S9, Canada; **Beverly M. Piroshco**, 3913 West 24th Avenue, Vancouver, B.C., V6S 1M1, Canada

[21] Appl. No.: **426,802**

[22] Filed: **Apr. 21, 1995**

[51] **Int. Cl.⁶** **C02F 3/30**

[52] **U.S. Cl.** **210/603; 210/605; 210/630; 210/719**

[58] **Field of Search** **210/603, 605, 210/623, 626, 630, 631, 719**

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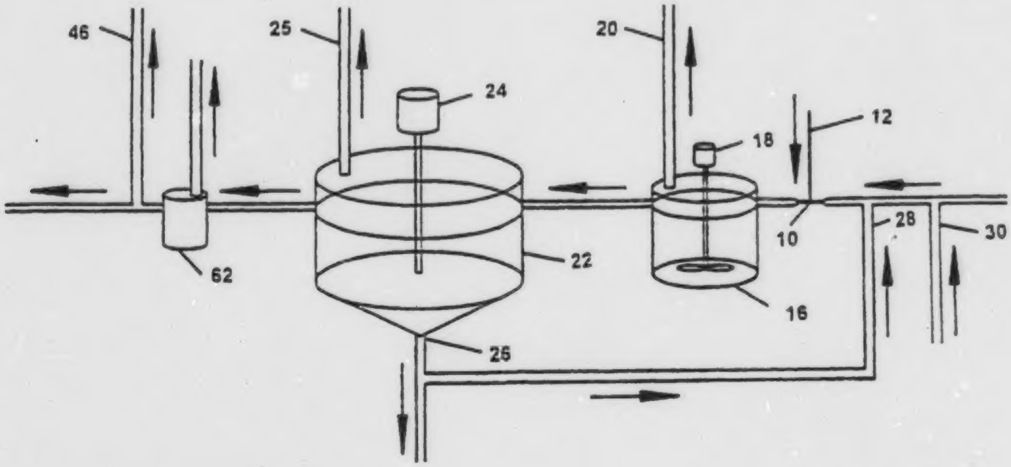
(List continued on next page.)

Primary Examiner—Christopher Upton
Attorney, Agent, or Firm—Chernoff, Vilhauer, McClung & Stenzel

[57] **ABSTRACT**

In accordance with the process of the invention, bacteria are used to provide hydrogen sulfide and carbonate compounds for treating solutions containing metal ions. To produce the hydrogen sulfide, the bacteria utilize sulfate ions present in the solution. Hydrogen sulfide produced by the bacteria is used to remove metals from the solution as insoluble metal sulfides. The process of the invention thereby removes sulfate and metal ions from the treated solution. The bacteria used are mixed populations, including strains of naturally-occurring sulfate reducing bacteria, which have been serially adapted and selected to be highly active with the particular solutions to be treated and with the carbon and hydrogen sources being utilized. The bacteria may be fed gaseous hydrogen and carbon nutrients produced by a partial oxidation burner. Carbonate compounds produced by the bacteria may be used to raise the solution pH for treatment and discharge. By controlling the addition of hydrogen sulfide and carbonate compounds to the solution, the preferential isolation of particular metal sulfide concentrates may be accomplished in separate precipitation steps, each with a specific pH and sulfide dosage.

29 Claims, 7 Drawing Sheets



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Appendix 2

Laboratory Scoping Testwork Final Report

August 1999

biomet

The *BioSulphide Process* to Treat AMD and Anaconda Tailings at Caribou Mine

Laboratory Scoping Testwork

Final Report

Prepared for:

Caribou Mine
Bathurst, New Brunswick

John McCombe
Mine Manager

August 1999

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Summary

Based on scoping level laboratory test results, the following conclusions were reached:

- Copper can be recovered selectively from AMD and tailings leachate solutions. The copper level in the treated water is <0.01 mg/L. Copper concentrate grades were low due to low copper levels in the AMD feed.
- Cadmium will precipitate with the copper.
- Zinc can be selectively recovered resulting in a treated solution containing approximately 1.0 mg/L Zn and a zinc concentrate grading 56% Zn. The zinc concentrate settles rapidly, approximately 6 cm/min., without additional flocculant.
- Hydroxide sludge can be admixed with AMD and used to remove ferric iron prior to the metals precipitation circuit. Significant copper and zinc can be leached from the sludge for subsequent recovery in the precipitation circuit.
- Iron and aluminum can be removed from solution following copper and zinc recovery using only bioreactor discharge as the alkaline source to pH 7. Manganese removal was incomplete, 4 mg/L in the treated water, using only biodischarge. Lime and/or limestone will be required to remove all of the Mn, if required.
- There was no indication that any component of the Caribou AMD or hydroxide sludge was deleterious to continuous bioreactor operation.
- Over 80% of the zinc contained in the Anaconda Pond A tailings can be extracted in a simple sulphate leach solution at 50 C, using the Caribou AMD as a sulphate and ferric iron source. Approximately 35% of the copper can be extracted under similar leaching conditions. Previous testwork indicated that other Anaconda tailings deposits at Caribou are more oxidized and the copper more readily extracted under mild sulphate leach conditions. Detailed results of the Anaconda tailings leach testing is reported under separate cover by RPC.

1.0 Introduction

Based on a site visit in 1998, several waste treatment options were defined for Caribou Mine that could utilize Biomet's BioSulphide Process™. A laboratory test programme was proposed to provide scoping level data for three process options: Case 1, Case 2 and Case 3 as described in a separate report titled **Potential Applications of the *BioSulphide Process* at Caribou**, dated 25 November, 1998. The laboratory programme was detailed in a proposal titled **The *BioSulphide Process* to Treat AMD and Anaconda Tailings at Caribou Mine, Proposed Development Program**, dated February, 1999.

The proposed laboratory test programme was approved by Caribou and commenced in February, 1999. Samples of acidic mine drainage (AMD) and hydroxide sludge were forwarded to Biomet in Vancouver and a fresh sample of Anaconda tailings from Pond A was sent to RPC in Fredericton to initiate the tailings leach testwork.

An interim report was issued 19 May, 1999 by fax to Robert Carreau at Caribou Mine.

2.0 Scope

2.1 Background

Based on a site visit and two reports provided by Caribou (RPC and Lorax), a preliminary review of process alternatives to treat acidic mine seepage as well as the Anaconda tailings using the BioSulphide Process was completed. The underlying objective is to treat the Anaconda tailings, including the overlaying sludge, to remove the mobile metals such as Cu, Zn and Pb so that the treated tailings can be deposited with mill tailings in the tailings pond. Co-deposition with lime hydroxide sludge is not a viable option by local regulation. Back-filling the underground mine is not a viable alternative based on discussions with site personnel.

Based on the probable recoverable metal in the Anaconda tailings, it is unlikely that a stand alone BioSulphide plant could be justified. Therefore, the alternatives included treatment plants that could be utilized long term to treat acidic mine drainage, thus eliminating lime treatment and the associated reagent and sludge storage costs.

The treatment objectives considered in developing the process alternatives were:

- Recover Cu and Zn and remove Pb from the mine water (into a Zn concentrate) to help off-set treatment costs and replace the existing lime plant. Also, this would remove these mobile metals from any process sludge and therefore allow sludge deposition with the mill tailings for long term storage, and

- Identify a method to re-treat the hydroxide sludge, overlaying the Anaconda tailings and currently discharged to the pit, to recover Cu and Zn and remove Pb for the reasons above, and
- Incorporate re-treatment of the Anaconda tailings for recovery of soluble Cu and Zn and to remove Pb, again to off-set costs and allow deposition in the tailings pond for long term storage, and
- Minimize capital and operating costs.

2.2 Process Alternatives

2.2.1 Case 1 – Acid Mine Drainage Treatment

Case 1 alternative is simply replacing the lime plant with a BioSulphide plant for long term acid water treatment. In this case, a zinc concentrate is produced (approximately 336,000 lb ZnS annually), also containing copper, lead and any cadmium in the drainage. Diesel fuel is used as the nutrient. The BioSulphide product solution is then treated with limestone for iron, aluminum and manganese removal into a high density carbonate sludge for disposal. A small amount of NaHS is produced as a co-product due to excess H_2S produced for process balance.

> *Assumptions to confirm: sulphate reduction rate, fuel utilization, consumable costs, concentrate quality.*
> *Data required: AMD – Fe^{2+}/Fe^{3+} ratio, SO_4^{2-}, acidity, cobalt.*

2.2.2 Case 2 – Add Hydroxide Sludge to Case 1 Flowsheet

Essentially the same flowsheet as Case 1 except the limestone addition is replaced with hydroxide sludge, which increases the recovered ZnS annually, due to contained $ZnSO_4$ in the sludge, and eliminates the limestone costs.

> *Assumptions to confirm: as above*
> *Data required: as above plus NNP and metal content of the hydroxide sludge*

2.2.3 Case 3 – Integrated Processing of AMD and Anaconda Tailings/Sludge

Case 3 is significantly more complex than either Case 1 or Case 2, but has the potential to contribute more to capital repayment if the metal recovery from the tailings is successful. The process requires dissolution of the Anaconda tailings/sludge using both AMD from the property and locally purchased sulphuric acid. The leached tailings are washed for disposal and the resultant leachate is then processed using the BioSulphide Process to recover separate copper and zinc concentrates.

The overlying sludge on the Anaconda tailings contains significant zinc values which can be recovered in the process. However, more sulphate must be reduced due to the increased sulphate from the sludge and sulphuric acid. This results in a significant production of co-product NaHS.

The tailings leach in warm acid (waste heat from the BioSulphide Process) is based on testwork previously conducted at RPC. It is likely that the Zn extraction during tailings leaching can be improved using a small amount of ferric iron, which might be supplied by the existing acid drainage. The resultant leached tailings should be acceptable for deposition in the tailings pond.

The data indicates that there is significant cobalt levels in the Anaconda tailings and hydroxide sludge. This has not been included as a potential revenue but represents a significant up side to the economics. In addition, it is possible to recycle sulphuric acid from excess H_2S, which might improve the process economics, depending on actual reagent costs for sulphuric acid and soda ash as well as local NaHS markets.

Assumptions to confirm: as above plus recoverable tailings quantities and grades, NaHS local pricing and market, sulphuric acid recycle from H_2S*, overall heat balance.*
Data required: as above plus tailings/sludge NNP, leaching curves for Cu, Zn, Pb, Cd, Fe, Al and Co under various conditions of density, acid drainage concentration, Fe^{3+} *concentration, temperature, free acid and retention time.*

2.3 Description of Scope

2.3.1 Laboratory Scoping

Objective: To provide confirmation operating data and process design criteria for prefeasibility purposes and determine overall process amenability.

Case 1: Treatment of Acidic Mine Drainage

Using a water sample from site, the objective is to operate a continuous laboratory system to define bioreactor operating criteria and to conduct precipitation scoping studies for zinc recovery. The product from the BioSulphide processing is then treated with lime and/or limestone to determine reagent requirements and final sludge quality for Fe, Al and Mn removal.

The apparatus includes a continuous single-stage bioreactor and two-stage precipitation circuit with process ancillaries and automatic controls. Metals of interest include Zn, Cu, Cd, Co, Pb, Fe, Al and Mn. Continuous sampling of bioreactor operating parameters and product solution.

Case 2: Treatment of AMD including sludge (flowsheet attached)

As above except lime/limestone is replaced with hydroxide sludge from site. Additional assays include NNP determination for sludge sample.

Case 3: Treatment of AMD/Anaconda Tailings re-treatment (flowsheet attached)

Laboratory scoping testwork on Anaconda Tailings and the overlaying sludge to provide confirmatory design criteria and reagent requirements for inclusion into Case 3 flowsheet evaluation. Standard batch laboratory tests to determine leachability curves for Cu, Zn, Pb, Cd, Co, Fe, Al with respect to slurry density, AMD addition rate, free acid concentration, temperature, Fe^{3+} concentration and temperature.

These tests were conducted independently at RPC in Fredericton, under the direction of Biomet.

Decision Point:

The results of the laboratory scoping test program described above will provide sufficient information to revise process estimates conducted during the initial review to determine if additional development work is warranted. Based on positive results, the project could proceed to the next step – Site Due Diligence and Prefeasibility Study.

3.0 Description of Testwork

3.1 Sample Characterisation

Approximately 100 litres of fresh acidic mine drainage was shipped from Caribou in plastic containers. The initial assay at Biomet showed 3,000 mg/L total sulphate in solution and pH 3. Detailed head assays are included with each test run, summarized below. The samples were stored cool prior to use to minimize sample oxidation.

A 20 litre pail of hydroxide sludge was received at Biomet, with the following characteristics:

a. Sludge density – 4.65% solids (w/w)
b. Alkalinity – 960 mg/L $CaCO_3$ equivalent
c. Free Lime - < 0.10% in solids
d. Assays – Al 6.54%, Cd 0.02%, Co 0.016%, Cu 0.57%, Fe 11.0%, Zn 9.8%.

A fresh composite sample of Anaconda Pond A tailings was forwarded to RPC, Fredericton, in May (labelled Pond A 5/99). The initial head assay was:

1.56% Cu, 1.66% Zn, 25.1% Fe, 2.22% Al, 2.45% Pb, 150g/t Cd, 100g/t Co

Due to sampling error from the head sample (non-homogeneous sample), the leach test results are compared to a calculated head from each test, for metallurgical balance purposes.

3.2 Test Procedures

Batch Precipitation Tests

All batch precipitation tests were conducted in laboratory 5 L stirred reactors and the precipitation reactor/clarifiers from a continuous laboratory apparatus, and used biogenic H_2S and alkalinity, as required, from a continuous 60 L column bioreactor which was operating on simulated sulphate solution (10 g/L SO_4). Standard laboratory ancillary apparatus was used for reagent preparation, product filtering and drying.

Test 100: Case 1 simulation. Test conducted in three stages; first stage with AMD and H_2S only at natural pH to recover copper and determine cadmium deportment, second stage added bioreactor alakalinity to pH ~3.5 to recover zinc, and the third stage added $CaO/CaCO_3$ to pH ~7.5 to remove remainder of metals.

Test 101: Case 2 simulation using $CaCO_3$ in the first stage to simulate addition of alkaline sludge for Fe removal prior to metal recovery using the BioSulphide Process.

Test conducted in three stages; the first to determine the pH change required to precipitate the Fe, second using biological alkalinity to maintain pH at ~3.5 while adding H_2S for zinc recovery, and finally addition of $CaO/CaCO_3$ to remove the remainder of the metals.

Test 102: Case 2 simulation similar to Test 101 except Caribou sludge was used in the first stage as the alkali source for iron removal prior to copper and zinc recovery using the BioSulphide Process.

Test 103: Case 2 simulation similar to Test 102 except additional control emphasized during the zinc precipitation circuit to improve zinc recovery and product grade. Note that the copper stage was simulated to remove effects of copper on the zinc product, however, samples were not taken of the copper stage products.

Test 104: Confirmation testing of the final neutralisation stage for Al, Fe and Mn removal from solution. Using the zinc stage clarifier overflow product from continuous precipitation testing. The alkalinity source was biogenic carbonate solution from the continuous Caribou bioreactor.

Continuous Precipitation Testing

Using the data from the batch precipitation testing, a continuous laboratory test circuit was operated where the Caribou AMD is first contacted with Caribou hydroxide sludge to pH approximately 3.6 and settled in a continuous clarifier, for ferric iron removal. The resulting iron clarifier overflow is contacted with biogenic H2S, using solution ORP setpoint control, then clarified for copper precipitate recovery. The copper stage clarifier overflow is pumped to a zinc stage reactor where additional H2S is introduced along with biogenic alkaline solution from the bioreactor, using solution pH and ORP setpoint control, and then settled in a continuous clarifier. The continuous circuit was operated in steady state from June 21-June 30.

The zinc clarifier overflow is used to feed the continuous bioreactor as required to produce sufficient H2S and alkalinity. Note that flocculant (0.001% solution) is added to both the copper and zinc stage clarifiers.

Standard laboratory 1 L graduated cylinder settling tests were conducted on the zinc sulphide product, at 5 different feed dilutions, to determine settling characteristics of the zinc product.

Continuous Bioreactor Operation

Using the treated prodcut solution from the batch tests, a 5 L laboratory bioreactor was accilimated to Caribou AMD during the period March-April, designated BERK 1 (indicating the original inoculum source from the Berkeley Pit). Following batch accilimation, semi-continuous feeding of the bioreactor was started to build sufficient biomass and determine operating criteria, using a simulated AMD containing approximately 3,000 mg/L total sulphate.

The continuous bioreactor operation was initiated on May 14, using the inoculum from column BERK 1. On June 18, the bioreactor feed was changed to Caribou zinc stage overflow product from batch testing (Tests 102 and 103) and then to continuous circuit product solution from June 21-30. The objective of the continuous bioreactor was to determine bioreactor operating criteria to obtain a final solution with 1500 – 2000 mg/L total sulphate and to determine if there was any solution component that would be detrimental to bioreactor operation.

Anaconda Tailings Leach Tests (Case 3)

RPC in Fredericton have conducted batch leaching tests using a fresh sample of Pond A tailings from site. Initially, comparative tests on a composite sample from drill core and a fresh sample from Pond A showed that the core sample had oxidized significantly, resulting in much higher soluble copper and zinc than a fresh sample.

A second fresh sample from Pond A was shipped to RPC for the testwork. Variables tested to determine Cu and Zn leachability (along with Fe, Pb, Al, Cd and Co) included temperature, retention time, pulp density, free acid concentration, ferric iron concentration and aeration.

A total of 20 batch tests were performed in the initial scoping testwork. The conditions for each batch test are included with the RPC data reports, under separate cover. A summary of the results is included in Section 4.0, following.

4.0 Results

4.1 Test Results

The test results from Batch Tests 100-104 are included in Appendix 1.

Results from continuous precipitation testing are included in Appendix 2. Table 1 shows the results of the feed pretreatment step using the Caribou hydroxide sludge sample, conducted in 3-4 L lots to supply continuous circuit feed. Table 2 shows the results of the continuous reactor/clarifier circuits for both the copper and zinc stages.

The results from zinc product settling are also included in Appendix 2.

Results from continuous bioreactor operation are included in Appendix 3. The results include an inoculum data sheet, providing details on the bioreactor inoculum source, and the continuous bioreactor data from May 14- June 30.

A summary of the RPC results todate is included in Appendix 4.

4.2 Discussion of Results

Batch Precipitation Tests

Test 100: The test results show that copper can be recovered separately, however, significant cadmium is co-precipitated at natural pH and the resultant copper precipitate is low grade (18.9% Cu). It is unlikely that a separate copper concentrate can be justified unless additional copper is available (eg. from sludge dissolution and/or tailings re-treatment). The second stage shows selective zinc recovery with a zinc concentrate grading 42% Zn, however, incomplete zinc recovery is shown (only 45% zinc recovery). The third stage shows effective metal removal with the exception of manganese which showed only 61% removal at pH 7.5. Additional alkalinity will be required to remove all of the manganese as there is insufficient Fe and Al present to co-precipitate all of the Mn at pH 7.5.

Test 101: The results show that alkali addition at natural pH did not remove any Fe, however an increase to pH 4.6 was required to precipitate the iron. During iron precipitation there was significant copper and zinc losses at pH 4.6. The zinc stage showed selective zinc removal, however, only 67% zinc recovery to a zinc concentrate grading 46% zinc, a slight improvement compared to test 100.

Test 102: The results show that iron can be removed very selectively, at pH ~ 3.6 – 3.7, using the Caribou sludge, with no loss of zinc. Note the increase in copper and zinc levels in solution following the addition of the sludge to the AMD in stage 1, indicating significant copper and zinc leaching from the sludge. The second stage again showed incomplete zinc recovery, which is addressed in the next precipitation test. The low zinc concentrate grade is due to incomplete zinc recovery and over addition of biodischarge solution.

Test 103: These results show much better zinc removal data – the final solution was 1 mg/L Zn and the product grade was 52.5% Zn. A target pH of 3.6 is satisfactory for the zinc stage at a solution ORP of approximately -200mV for effective zinc recovery.

Test 104: These data show complete removal of aluminum and iron after addition of only 50mL of biodischarge to 3 litres of product solution(pH 7.1). However, additional biodischarge is required to remove the manganese. It is likely that a small amount of lime addition will be required to completely remove Mn, if required. Note that aluminum re-dissolves above pH 7.

Continuous Precipitation Testing

Feed pretreatment using hydroxide sludge, Table 1 Appendix 2, showed that approximately 10 mL sludge per litre of AMD will remove ferric iron and also dissolve a significant portion of the copper and zinc in the sludge. Additional optimisation work will be required during mini-pilot operation to maximize sludge utilization and copper and zinc extraction.

Continuous precipitation circuit data showed that a steady state can be reached where copper can be recovered selectively to reduce copper in the product solution to <0.01 mg/L. Zinc recovery is also highly selective, resulting in zinc levels in the treated solution of approximately 1 mg/L and a final product grade of 56.6% Zn.

The settling data for the zinc concentrate product from continuous testing showed rapid settling (Test 2) when diluted to 10% of the underflow density with fresh zinc reactor product. Additional optimisation work will be required during mini-pilot operation.

Continuous Bioreactor Operation

The Caribou bioreactor operated at a continuous steady state at pH approximately 7, -200 to –300mV and stabilised at approximately 1,800 mg/L total sulphate in the product solution, compared with 1500-2000 mg/L target. There were no deleterious components in the AMD water sample from site for continuous bioreactor operation.

RPC - Tailings Leach Results

The results of the Anaconda Pond A tailings leach testing that is in progress at RPC show that significant zinc can be extracted, 82%, using a weak sulphate solution, 5 g/L free SO_4 and 1 g/L Fe^{3+}, at 10% solids and 50 C. Increased ferric iron concentration, to 5 g/L, increased the Zn extraction to 86%. Additional free acid, aeration and higher temperature did not improve Zn extraction. The leach duration for zinc extraction is expected to be 8 hours or less.

Under the same conditions, copper recovery was 32%. There is no improvement with aeration but a significant improvement with Fe^{3+} additions of 5 g/L, resulting in 39% copper extraction. Pulp density is probably not a significant factor in copper extraction. Leach kinetics are very rapid for copper, typically < 4 hours.

Higher temperature leaching at 90 C was deleterious to both copper and zinc extraction.

Tailings Comparison

a. A typical Caribou mill tailings (MTD 15 April, 1998) assayed:

0.21% Cu, 1.16% Pb, 2.68% Zn and 32.22% Fe

b. Anaconda Pond A Tailings from Test # 14 at RPC assayed:

2.05% Cu, 2.45% Pb, 1.66% Zn and 25.1% Fe

c. The residue from Test #14 (best Cu and Zn extraction) at RPC assayed:

1.37% Cu, 2.09% Pb, 0.38% Zn and 24.6% Fe

when adjusted for a 9.1% weight loss to compare with other tailings, assayed:

1.25% Cu, 1.90% Pb, 0.35% Zn and 22.4% Fe

The total metal loading, in kg metal/tonne tailings, for the three tailings products compares:

Product	Mill Tailings	Anaconda Pond A	Leach Residue
Total	362.7	307.7	258.6
Cu and Zn	28.9	37.1	16.0

The "Total" metal loading is predominantly iron, which is not as potentially mobile or toxic as copper and zinc. The lead is not very mobile and would form a lead sulphate precipitate if leached naturally by AMD sources. Therefore, the combined Cu and Zn comparison is a better comparison of relative potential toxicity.

Note that the Leach Residue product is the result of an acid sulphate leach at 50 C and it is unlikely to easily leach in the future. Standard leachability tests as well as humidity cell testing should be conducted on all three tailings products for comparative purposes as part of the next stage of testwork.

Conclusions and Recommendations

4.3 Conclusions

- Copper can be recovered selectively from AMD and leach solutions. The copper level in the treated water is <0.01 mg/L. Copper concentrate grades were low due to low levels in the AMD feed. Additional copper precipitation work will be required to include tailings leachate solution with higher copper levels.
- Cadmium will precipitate with the copper.
- Zinc can be selectively recovered resulting in a treated solution containing approximately 1.0 mg/L Zn and a zinc concentrate grading 56% Zn. The zinc concentrate settles rapidly, approximately 6 cm/min., without additional flocculant.
- Hydroxide sludge can be used to remove ferric iron prior to the metals precipitation circuit and significant copper and zinc can be leached from the sludge for subsequent recovery in the precipitation circuit.
- Iron and aluminum can be removed from solution following copper and zinc recovery using only bioreactor discharge as the alkaline source to pH 7. Manganese removal was incomplete, 4 mg/L in the treated water, using only biodischarge. Lime and/or limestone will be required to further reduce Mn levels in the treated water.
- There was no indication that any component of the Caribou AMD or hydroxide sludge was deleterious to continuous bioreactor operation.
- Over 80% of the zinc contained in the Anaconda Pond A tailings can be extracted in a simple sulphate leach solution at 50 C, using the Caribou AMD as a sulphate and ferric iron source. Copper extraction was 32-39%, depending on ferric iron concentration.

4.4 Recommendations

The results of the laboratory scoping testwork summarized herein show that continued development of the project is warranted. It is recommended that the Site Due Diligence and Prefeasibility Study stages of the overall proposed programme are initiated, using Case 3 flowsheet alternative. Also, it is recommended that a mini-pilot circuit is operated at site to better define the process variables in continuous steady state, prior to site piloting, and to integrate Anaconda tailings leaching into the flowsheet (Case 3).

Comparative leachability tests and humidity cell testing should be conducted on the mill tailings, Anaconda tailings and the combined residue from BioSulphide testing to determine relative metal mobility and potential toxicity.

Appendix 1

Batch Precipitation Test Results

Caribou Pit Water - ide precipitation.

Volume (mL)	Alkalinity Add'n	Alkalinity Amount	H_2S Contact	Stage	pH	ORP (mV)	Solution Assay Results Al (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	S (mg/L)	Zn (mg/L)
3000	-	-	yes	1	2.59	489	91.6	1.44	22.2	201	78.4	1030	707
2975	-	-	yes	1	2.24	154	91.6 *	0.75	0.09	197	78.4 *	1030 *	707 *
2950	-	-	yes	1	2.24	84	91.6 *	0.07	0.02	196	78.4 *	1030 *	683
3125	bio disch	200	yes	2	3.55	-114	82.4	<0.01	0.02 *	181	69.2	1030 *	365
3300	CaO/CaCO$_3$	200	-	3	7.55	-141	<0.01	<0.01	0.01	0.08	27.2	947	1.36

* estimated value

bio disch - bioreactor discharge

Stage	Removal (%) Al	Cd	Cu	Fe	Mn	Zn
1	0	0	0	0	0	0
1	0	48	100	2	0	0
1		95	100	2	0	3
2	5	99	100	5	7	45
3	100	99	100	100	61	100

Stage	Solids Assay (%) Al	Cd	Cu	Fe	Mn	Zn
1	-	-	18.90	-	-	-
2	-	0.010	-	-	-	42.2
3	0.72	-	-	1.59	0.33	-

Stage	Description
1	H_2S gas until ORP declines sharply, fliter
2	Raise pH to 3.7 with bioreactor discharge & H_2S gas, decant then filter sludge
3	Raise pH to 7.5 or 8.0 with CaO/CaCO$_3$, filter

Caribou Pit Water - ide precipitation.

Volume (mL)	Alkalinity Add'n	Alkalinity Amount	H_2S Contact	Stage	pH	ORP (mV)	Solution Assay Results					
							Al (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Zn (mg/L)
3000	$CaCO_3$	100	no	1	2.65	512	89	1.38	21.3	183	75.9	678
2975	$CaCO_3$	100	no	1	4.62	289	89 *	1.34	16.7	4	75.9 *	607
3055	bio disch	80	yes	2	3.62	-66	no sample					
3130	$CaO/CaCO_3$	200	no	3	7.22	10	<0.01	<0.01	<0.01	0.01	53.4	151

* estimated value

bio disch - bioreactor discharge

Stage	Removal (%)					
	Al	Cd	Cu	Fe	Mn	Zn
1	0	0	0	0	0	0
1	1	4	22	98	1	11
2						
3	100	99	100	100	29	78

Stage	Solids Assay (%)					
	Al	Cd	Cu	Fe	Mn	Zn
1	-	-	0.34	-	-	-
2	-	0.284	-	-	-	45.9
3	0.88	-	-	0.35	0.35	-

Stage	Description
1	CaCO3 until ORP decline and colour change, filter
2	Raise pH to 3.7 with bioreactor discharge & H_2S gas, decant then filter sludge
3	Raise pH to 7.5 or 8.0 with $CaO/CaCO_3$, filter

Caribou Pit Water - de precipitation.

Volume (mL)	Alkalinity Add'n	Alkalinity Amount	H_2S Contact	Stage	pH	ORP (mV)	Solution Assay Results					
							Al (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Zn (mg/L)
3000	-	-	no	1	2.56	537	78.2	1.22	18.7	151	66.3	594
3047	OH^- sludge	72	no	1	3.66	440	95.4	1.58	25.2	6.01	84	751
3367	bio disch	345	yes	2	4.49	118	39.2	<0.01	0.18	6.01 *	84 *	278
3342	bio disch	0	yes	2	4.13	-105	38.1	<0.01	<0.01	2.75	67	198
3392	CaO/CaCO$_3$	75	no	3	9.69	-47	0.27	<0.01	<0.01 *	0.01	1.99	0.5

* estimated value

bio disch - bioreactor discharge

Stage	Removal (%)					
	Al	Cd	Cu	Fe	Mn	Zn
1	0	0	0	0	0	0
1	0	0	0	96	0	0
2	51	99	99	96	0	0
2	46	99	100	98	0	63
3	100	99	100	100	97	100

Stage	Solids Assay (%)					
	Al	Cd	Cu	Fe	Mn	Zn
1	-	-	0.24	-	-	1.1
2	-	-	1.67	-	-	32.7
3	1.73	-	-	0.25	2.40	-

Stage	Description
1	Raise pH to 3.5 or 3.7 with OH^- sludge, then filter
2	Maintain pH 3.5 or 3.7 with bioreactor discharge while applying H2S, then filter
3	Raise pH to 7.5 or 8.0 with CaO/CaCO$_3$, then filter

Caribou Pit Water - ide precipitation.

Volume (mL)	Alkalinity Type	Alkalinity Amount added	H_2S Contact	Stage	pH	ORP (mV)	Solution Assay Results									
							Al (mg/L)	Cd (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)	Mn (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)	
3000	-	-	no	1	2.59	472	102	1.52	1.11	24.1	175	85.9	0.38	1.40	773	
3075	OH^- sludge	75	no	1	3.44	432	119	1.75	1.29	32.0	6.47	96.5	0.52	2.26	868	1
3045	-	-	yes	2	2.90	-37	no sample									2
3295	bio disch	370	yes	3	3.61	-188	112	<0.01	0.01	<0.01	0.05				0.99	3
3265	$CaO/CaCO_3$	50	no	4	7.15	-186	<0.01	<0.01	0.01	<0.01	0.05					4
3315	$CaO/CaCO_3$	0	no	4	8.60	37	<0.01	<0.01	0.01	<0.01	<0.01		<0.01			5

* estimated value

bio disch - bioreactor discharge

Stage	Removal (%)					
	Al	Cd	Cu	Fe	Mn	Zn
1	0	0	0	0	0	0
1	0	0	0	96	0	0
2						
3	0	99	0	100	100	100
4	100	99	0	100	100	100
4	100	99	0	100	100	100

Stage	Solids Assay (%)								
	Ag	Al	Ca	Cd	Co	Cu	Fe	Mn	Zn
1						0.175	22.9		0.90
2	2.0					23.1			
3		0.14		0.005					52.5
4		3.19	30 5		0.02		0.31	2.45	

Stage	Description
1	Raise pH to 3.3 or 3.4 with OH^- sludge only, then filter
2	Lower ORP to 0 or -100 mV with H_2S gas, then filter
3	Raise pH to 3.7 & lower ORP to -200 mV with H_2S gas & biodischarge, then filter
4	Raise pH to 8.5 with $CaO/CaCO_3$, then filter

Caribou Pit Water - de precipitation.

Volume (mL)	Alkalinity Type	Alkalinity (mL)	H_2S Contact	Stage	pH	ORP (mV)	Solution Assay Results		
							Al (mg/L)	Fe (mg/L)	Mn (mg/L)
3000	-		no	1	4.61	61	46.6	9.98	87.8
3050	bio	50	no	1	7.10	45	<0.01	0.11	78.1
3090	bio	90	no	1	8.74	136	2.02	<0.01	4.94

* estimated value

Stage	Removal (%)		
	Al	Fe	Mn
1	100	99	10
1	96	100	94

Stage	Solids Assay (%)			
	Al	Ca	Fe	Mn
1	1.8	28.9	0.41	2.74

Stage	Description
1	Raise pH to 7.5 with lime/limestone

Note: Al removal decreases because the pH increases.

Appendix 2

Continuous Precipitation Circuit Test Data

BIOMET MINING - Caribou Continuous Biosulphide Testing

Date	Volume (L)	sludge (mL)	sludge (g)	pH	Untreated Feed				Treated Feed				% change			
					Al (ppm)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Al (ppm)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Al	Cu	Fe	Zn
18-Jun	3.0	66	6.4	3.60	108	26	186	836	129	36	4	1000	19	38	-98	20
24-Jun	3.8	40	3.9	3.94	45	11	113	365	60.5	19.3	21.7	565	34	80	-81	55
25-Jun	3.5	25	2.4	3.61	45	11	113	365	63.3	17.9	7.58	489	41	67	-93	34

Note: Fe decreases, Cu&Zn increase

Note: Treated Feed numbers vary due to mixing in circuit feed vessel.

TABLE 1: Continuous Circuit Feed Pretreatment Data

BIOMET MINING - Caribou \ .nuous Biosulphide Testing

Date		Time	Day	FEED DATA *								CU STAGE												
							Assayed Values										Assayed Values, % Recovery							
				Feed Level L	Feed Add'n L	Feed Rate mL/min	pH	Al ppm	Cu ppm	Fe ppm	Zn ppm	Biogas Rate mL/min	Floc Add'n ppm	Floc Add'n L	pH	ORP mV	Al ppm	Al %	Cu ppm	Cu %	Fe ppm	Fe %	Zn ppm	Zn %
June	21	19.50	1	2.4	0.0	-	3.60					168	12.08	1.0	-	-		-		-		-		-
	22	10.00	1	1.6	0.00	1.0	3.60					202	12.08	-	-	-330		-		-		-		-
	22	20.00	2	0.0	2.60	2.7	3.60					168	12.08	-	2.86	-26		-		-		-		-
	23	16.00	3	0.0	1.35	2.2	3.88	129	36.2	4.32	1000	168	12.08	-	2.79	-89		-		-		-		-
	24	8.75	3	0.0	1.41	1.3	3.94					168	12.08	-	2.83	-90		-		-		-		-
	24	19.50	4	0.3	2.10	1.8	3.94					168	12.08	-	2.81	136		-		-		-		-
	25	12.00	5	1.6	3.00	0.8	3.61	47.7	15.4	31.5	500	168	12.08	-	2.82	112	107	0	14.8	59.1	7.10	60	871	0
	27	16.25	7	2.6	1.95	0.7	3.61	60.0	19.4	23.4	586	176	12.08	1.0	2.87	58	88.4	0	9.44	51.3	7.45	68	755	0
	28	11.00	7	1.9	2.58	2.4	3.61	60.5	19.3	21.7	565	176	12.08	-	2.91	-65	73.1	0	7.18	62.8	12.1	44	625	0
	29	10.00	8	2.35	0.70	1.5	3.61	63.3	17.9	7.58	489	176	12.08	-	2.95	140	64.4	0	1.80	89.9	11.2	0	566	0
	30	17.00	10	2.35													60.4	0	<0.01	>99.9	7.46	1.6	498	0
Totals					15																			

* Feed has been treated with OH sludge

NOTE: ZnS solids 56.6%

TABLE 2: Continuous Precipitation Circuit Data (Head Assays Adjusted) (page 1 of 2)

BIOMET MINING - Caribou .uous Biosulphide Testing

Date		Time	Day	ZINC STAGE													
				Biogas Rate *L/min**	Biodis Level *Litres*	Biodis Rate *mL/min*	Floc Add'n *ppm*	pH	ORP *mV*	Assayed Values, % Recovery							
										Al *ppm*	Al *%*	Cu *ppm*	Cu *%*	Fe *ppm*	Fe *%*	Zn *ppm*	Zn *%*
June	21	19.50	1	-	2.0	-	12.08										
	22	10.00	1	-	2.0	0.0	12.08	-	-		-		-		-		-
	22	20.00	2	-	2.0	0.0	12.08	-	-		-		-		-		-
	23	16.00	3	588	2.0	0.0	12.08	2.73	-1		-		-		-		-
	24	8.75	3	672	1.7	0.3	12.08	3.94	-211		-		-		-		-
	24	19.50	4	672	1.5	0.2	12.08	4.03	-249		-		-		-		-
	25	12.00	5	756	1.4	0.1	12.08	3.52	-168	85.8	0	<0.01	>99.9	9.51	70	2.30	99.5
	27	16.25	7	840	1.2	0.1	12.08	4.08	-195	78.1	0	<0.01	>99.9	7.72	67	0.76	99.9
	28	11.00	7	840	0.9	0.2	12.08	4.04	-50	69.9	0	<0.01	>99.9	8.32	62	1.26	99.8
	29	10.00	8	840	0.0	-	12.08	3.51	-91	62.3	2	<0.01	>99.9	9.01	0	1.00	99.8
	30	17.00	10				12.08			60.0	5	<0.01	>99.9	9.12	0	3.68	99.2
Totals					1.1												
					%disch	7.0											

* Feed has been treated with OH

NOTE: ZnS solids 56.6%

* Intermittent pumping rate, controlled by ORP setpoint

TABLE 2: Continuous Precipitation Circuit Data (Head Assays Adjusted) (page 2 of 2)

TSL
ASSAYERS

TSL Assayers Vancouver
8282 Sherbrooke St.
Vancouver, B.C.
V5X 4R6
Tel: (604) 327-3436
Fax: (604) 327-3423

Quality Assaying for over 25 Years

Assay Certificate

9V-0254-PA1

Jul-20-99

Company: **Biomet Mining Corp.**
Project: CARI
Attn: Doug Warkentin

We *hereby certify* the following assay of 3 pulp samples submitted Jul-20-99 by Biomet Mining Corp..

Sample Name	Al %	Ca %	Fe %	Mn %	Zn %
0708-2	1.80	28.9	0.41	2.74	
Circuit					56.6
Counter					31.6

Certified by ____________________

Settling Test Data

Run	level (mL)	(cm)	time (min)								
1	1000	35.75	0.00	2	1000	35.75	0.00	3	1000	35.75	0.00
	960	34.32	0.67		970	34.68	0.42		950	33.96	1.00
	900	32.18	1.25		950	33.96	1.00		790	28.24	2.00
	710	25.38	1.83		765	27.35	1.42		660	23.6	2.42
	470	16.8	2.05		560	20.02	1.67		490	17.52	3.50
					395	14.12	2.00		250	8.938	4.25
	1000	35.75	0.00		225	8.044	3.00		140	5.005	5.00
	970	34.68	0.42		105	3.754	3.50		70	2.503	12.00
	950	33.96	1.00		40	1.43	100.0				
	765	27.35	1.42								
	560	20.02	1.67								
	395	14.12	2.00								
	225	8.044	3.00								
	105	3.754	3.50								
	1000	35.75	0.00								
	950	33.96	1.00								
	790	28.24	2.00								
	660	23.6	2.42								
	490	17.52	3.50								
	250	8.938	4.25								
	140	5.005	5.00								
	70	2.503	12.00								
	40	1.43	100.0								
4	0	51.58	0	5	0	51.58	0				
	17	50	2		10	50.65	0.5				
	170	35.75	13		340	19.91	35				
	320	21.77	25		425	11.99	60				
	435	11.06	60		475	7.329	180				
	0	51.58	0								
	10	50.65	0.5								
	340	19.91	35								
	425	11.99	60								
	475	7.329	180								
	500	5	1440								

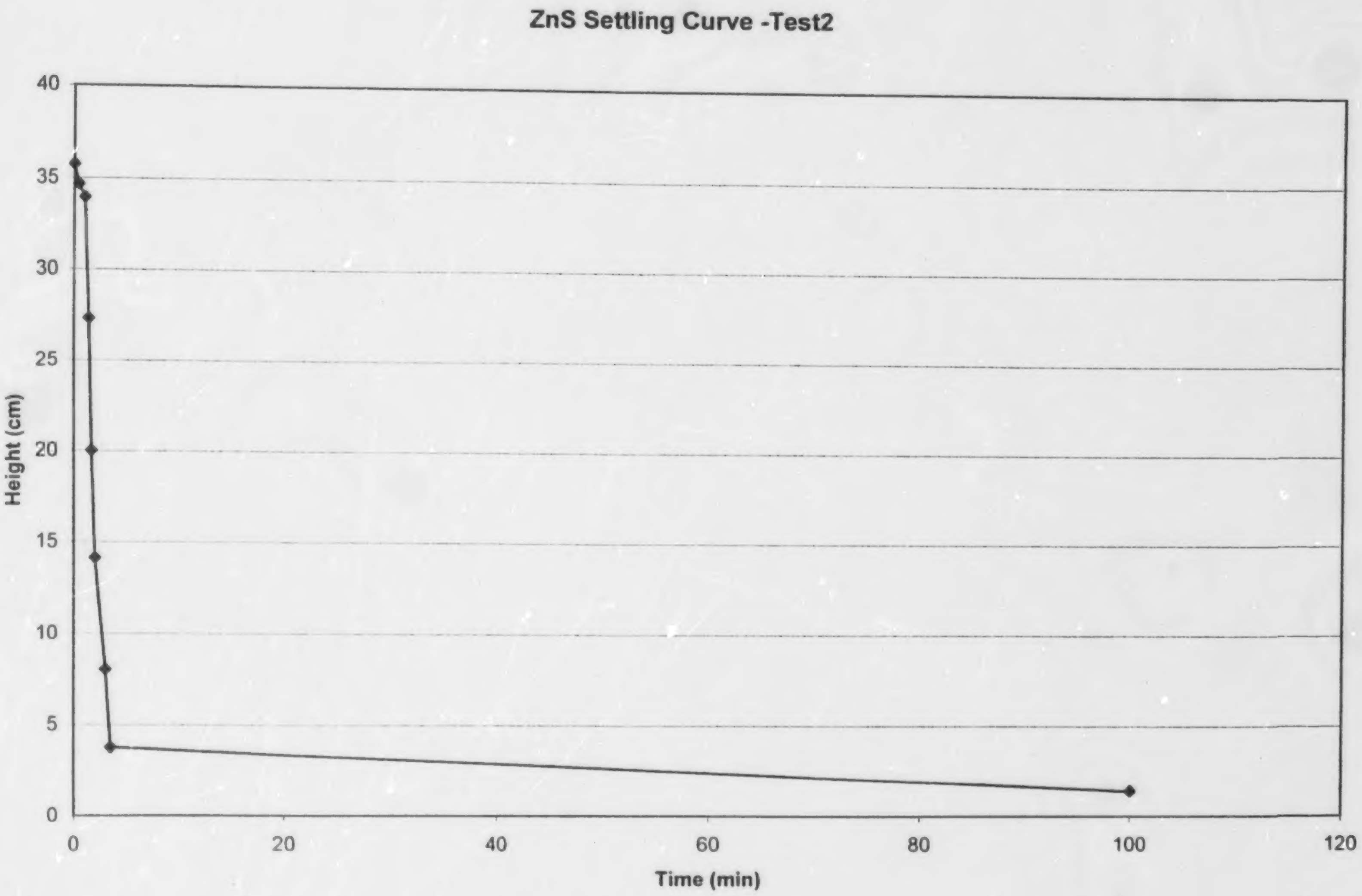

FIGURE 1: ZnS Precipitate Settling Curve with 10% Dilution Initial Solids Density

Appendix 3

Continuous Bioreactor Test Data

1. Start-up water characteristics

I.D.	CARI
Date	May 14, 1999
Start-up water origin / list of components	BERK Column I
Volume inoculum (L)	5.68
Volume feed (L)	0
% inoculum	100%
TSS (mg/L)	4635
VSS (mg/L)	1585.00
Wet Cell Volume (WCV)	2.25%
Wet Cell Mass (WCM)	2.00%
Start-up water sulfate concentration (g/L)	3
pH	7.73
Temperature (°C)	20
ORP (mV)	-397

2. Inoculum development conditions

Number of days in development	30
Method of feed	continuous
Temperature (C) target	30
Temp. (C) min. / max.	20 / 28
pH target	6.5
pH min. / max.	6.0 / 8.0
ORP (mV) target	-200
ORP (mV) min. / max.	-200 / -450
Nutrient mix	4 g/L Na_2SO_4 0.3 g/L $MgCl_2$ 0.2 g/L $CaCl_2$ 0.4 g/L $(NH_4)_2SO_4$ 0.08 g/L KH_2PO_4 0.01 g/L Yeast Extract 0.04 g/L $FeSO_4 \cdot 7H_2O$
Gas composition	14% H_2, 14%CO, 5%CO_2 & 67%N_2

3. Inoculum average characteristics (taken from the previous 30 days)

Ave. sulfate reduction rate (g SO_4/Ld)	0.9

4. Reactor characteristics

Volume (L)	5.68
Reactor material	PVC
Shape	column
Dimensions	4" x 37"
Fittings	1/4" stainless & plastic tubing & 3/4" plastic tubing
Media type	high-void space plastic spheres

Filled out by___________

BIOMET MINING - Caribou Continuous Bioreactor Operation

				Feed						Feed					Bioreactor											
Date	Time	Day	NOTES	Ret'n Actual days	Ret'n Target days	pH	T_{feed} °C	ORP mV	$SO_4^=$ mg/L	H_2 Rota. read	N_2 Rota. read	CO Rota. read	CO_2 Rota. read	Gas Recycle mL/min	Soln Recycle mL/min	DATA $T_{reactor}$ °C	pH	ORP mV	$SO_4^=$ mg/L	WCV %	WCM %	TSS mg/L	VSS mg/L	SRR mg/L-day	5-Day Ave SRR mg/L-day	Specific SRR
inoc																				2.25	2.00	4635	1585	-	-	
14-May-99	14:00	1		-	-		20		3,000	8	95	35	0	15	31	30	8.80	-428	-					-	-	
17-May-99	7:45	4		-	-		20		3,000	0	30	40	8	15	31	30	8.26	-399	1369	5.20	1.36	2176	1208	-	-	
18-May-99	9:00	5		-	-		20		3,000	-	-	-	-	15	31	30	8.29	-	319					1,048	-	
20-May-99	10:00	7		-	12		20		3,000	50	0	12	8	15	31	30	8.82	-446	127					96	-	
21-May-99	9:00	8		1	12		20		3,000	8	100	35	0	15	31	30	8.61	-	751					237	276	
25-May-99	11:00	12		-	12		20		3,000	8	95	35	0	15	31	30	8.46	-433	257					123	301	
26-May-99	9:00	13		19	12		20		3,000	8	95	35	8	15	31	30	8.04	-416	239	3.13	3.39	2733	2221	68	314	0.030
28-May-99	11:30	15		38	12		20		3,000	8	35	35	15	15	31	30	8.31	-380	145					72	119	
31-May-99	12:30	18		28	12		20		3,000	40	0	35	16	15	31	30	7.50	-365	152					30	106	
1-Jun-99	11:00	19	RT 12 to 10 day	57	12		20		3,000	8	0	35	15	15	31	30	7.23	-400	58					111	81	
2-Jun-99	18:30	20		29	10		20		3,000	8	95	35	15	15	31	28	7.37	-384	55					35	63	
3-Jun-99	18:00	21		19	10		20		3,000	9	90	35	13	15	31	29	7.72	-367	45					59	62	
4-Jun-99	13:00	22		-	10		20		3,000	9	90	35	20	15	31	29	7.67	-351	97	6.46	4.11	838	208	-52	37	-0.252
7-Jun-99	18:30	25		34	10		20		3,000	9	90	10	15	15	31	29	7.74	-376	-					-	31	
8-Jun-99	21:00	26	RT 10 to 9 day	29	9		20		3,000	9	95	35	16	15	31	29	7.65	-389	600					-	8	
10-Jun-99	18:00	28		23	9		20		3,000	9	94	34	13	15	31	29	7.78	-379	884	5.42	2.51	1217	217	-102	-19	-0.473
14-Jun-99	11:00	32		23	9		20		3,000	10	0	34	13	15	31	29	7.34	-369	650					101	-11	
15-Jun-99	17:30	33	estimate feed level	16	9		20		3,000	0	95	34	13	15	31	29	7.76	-204	-					-	0	
16-Jun-99	16:30	34		14	9		20		3,000	10	100	34	25	15	31	29	7.55	-381	968					-	0	
17-Jun-99	8:30	35		-	9		20		3,000	10	100	34	25	15	31	-	-	-	617					356	71	
18-Jun-99	13:00	36	changed feed to CAB Batch test product	29	9	6.47	20	89	2,780	10	100	34	25	15	31	29	7.41	-379	884					-233	45	
21-Jun-99	8:30	39	estimate feed level	20	9	6.47	20	89	2,780	-	-	-	-	15	31	29	7.12	-333	717					103	45	
22-Jun-99	11.45	40		6	9	6.47	20	89	2,780	10	100	34	25	15	31	29	7.15	-319	834					29	51	
24-Jun-99	12:00	42	leak at heater - lost appx 1L	5	9	6.47	20	89	2,780	10	95	34	25	15	31	29	6.82	-200	934	1.56	2.62	444	94	153	81	1.630
25-Jun-99	13:30	43	replaced heater fitting	4	9	6.47	20	89	2,780	8	95	45	30	15	31	29	6.90	-330	1836					-706	-131	
28-Jun-99	8:15	46		5	9	6.47	20	89	2,780	8	95	46	30	15	31	30	6.74	-215	1736					211	-42	
29-Jun-99	8:45	47		3	9	6.47	20	89	2,780	8	100	52	30	15	31	29	6.98	-221	1803					226	-18	
30-Jun-99	13:30	48		-	9	6.47	20	89	2,780	8	100	52	30	15	31	29	6.98	-221	1803	1.56	1.47	2013	1319	0	-23	0.000

TABLE 3: Continuous Bioreactor Operating Data

Appendix 4

Summary of RPC Leach Tests
Anaconda Tailings Pond A

BIOMET MINING - Caribou Project - Anaconda Pond A Tailings Leach Data

Summary of RPC Test Results

Test No.	Sample	Temp. (C)	Density (%solids)	H2SO4 (g/L)	Fe3+ (g/L)	Aeration (mL/min)	Calc. Head Assay		% Extraction	
							% Cu	% Zn	Cu	Zn
1	Pond A 3/99	20	20	0.5	1.0		1.53	2.09	20.8	17.0
2	Core Comp	20	20	0.5	1.0		1.83	2.28	45.8	64.5
3	Pond A 3/99	20	20	0.5	0.0		1.95	1.87	21.1	18.4
4	Core Comp	20	20	0.5	0.0		2.06	2.09	38.7	34.6
5	Pond A 5/99	20	20	0.5	1.0		1.91	2.51	22.5	37.5
6	Pond A 5/99	10	10	0.5	1.0		2.26	3.27	28.6	45.8
7	Pond A 5/99	20	20	0.0	1.0		1.62	2.31	26.9	46.3
8	Pond A 5/99	20	20	5.0	1.0		1.84	2.46	31.0	45.1
9	Pond A 5/99	20	20	0.5	0.0		1.71	2.28	22.0	41.2
10	Pond A 5/99	20	50	0.5	1.0		1.81	2.39	17.0	35.3
11	Pond A 5/99	50	10	0.5	1.0		1.97	2.04	26.6	73.4
12	Pond A 5/99	50	10	0.5	1.0	3628	1.91	2.05	27.2	77.0
13	Pond A 5/99	50	10	5.0	1.0		2.10	2.12	31.9	81.5
14	Pond A 5/99	50	10	5.0	5.0		2.05	2.44	39.2	85.9
15	Pond A 5/99	50	10	5.0	5.0	3628	2.03	1.97	38.7	85.3
16	Pond A 5/99	50	50	5.0	5.0		1.83	2.89	28.3	60.8
17	Pond A 5/99	90	50	5.0	5.0		1.75	2.43	-	71.2
18	Pond A 5/99	90	50	10.0	5.0		1.74	2.48	-	65.3
19	Pond A 5/99	90	50	10.0	0.0		1.74	2.82	-	67.0
20	Pond A 5/99	90	20	10.0	0.0		1.71	2.39	-	67.5

Appendix 3

RPC Report, November 1999

Metals Extraction Leach Tests on Caribou Mines Anaconda Tailings and Sludge Composite Samples

rpc
The Technical
Solutions
Centre

Le centre
de solutions
techniques

November 23, 1999

Mr. Brad Marchant
Biomet Mining Corporation
Unit 360 - 3771 Jacombs Road,
Richmond, BC
V6V 2L9
Fax: (604) 276-8601

Dear Mr. Marchant,

RE: Metals Extraction Leach Tests on Caribou Mines Anaconda Tailings and Sludge Composite Samples
Report No.: PET/99/341
Job No.: 08060356/001

We are pleased to present the final results from our metals extraction leach tests conducted on the Caribou Mines Anaconda Tailings samples. A total of 24 tests were carried out to evaluate the leachability of the Anaconda tailings and the hydroxide sludge samples. Only the Pond A tailings sample was evaluated in the program. The final test matrix is presented in Table 1.

Varying test parameters inclusive of temperature (20, 50, 90 °C), slurry density (10, 20, 50%), retention time (4, 8, 24 hr), aeration (yes, no), H_2SO_4 concentration (0, 0.5, 3.5, 5.0, 10.0 g/l) and ferric sulphate addition (0.0, 1.0, 5.0 g/l) were evaluated. Each test was carried out in 2 litre reactor vessels. A 0.5 to 1.5 litre aliquot of the prepared Caribou acid mine drainage head solution and composite solid sample were added to each vessel. The tanks were agitated at a rate sufficient to keep the solids suspended (450-500 rpm). The tanks were also monitored for pH and ORP. Solution samples were removed from the vessels and filtered. Solids were returned to the leach tanks. Solution samples were assayed for Cu, Zn, Pb, Cd, Co, Fe, and Al concentration. Final leach residues were assayed for Cu, Zn, Pb, Cd, Co, Fe, and Al, after washing with distilled water and drying.

Based on the test results from copper and zinc extraction data, the best conditions to treat the Pond A tailings were found to be at 50°C, 10% slurry density, 5 g/L H_2SO_4 and 5 g/L ferric addition with aeration (Test 15). The addition of 5 g/L ferric, however, will not likely be practical due to the high reagent cost. At lower ferric addition (Test 11 & 12), the aeration did not affect the leach results. The leach tests were also conducted at various retention times from 4 hours up to 24 hours. The results in test 11 and 12 showed that a maximum retention time of 4 hours would be appropriate.

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http://www.rpc.ca

Table 1
Optimization Test Matrix

Test #	Sample ID	Temp. (C)	Slurry Density (%)	Retention Time (hrs)	H_2SO_4 Add'n (g/L)	Ferric Add'n (g/L)	Aeration
1	Pond A	20	20	24	0.5	1.0	No
2	Pond A[1]	20	20	24	0.5	1.0	No
3	Pond A	20	20	4	3.5	0.0	No
4	Pond A[1]	20	20	4	0.5	0.0	No
5	Pond A	20	20	24	0.5	1.0	No
6	Pond A	20	10	24	0.5	1.0	No
7	Pond A	20	20	24	0.0	1.0	No
8	Pond A	20	20	24	5.0	1.0	No
9	Pond A	20	20	24	0.5	0.0	No
10	Pond A	20	50	24	0.5	1.0	No
11	Pond A	50	10	8	0.5	1.0	No
12	Pond A	50	10	8	0.5	1.0	Yes
13	Pond A	50	10	8	5.0	1.0	No
14	Pond A	50	10	8	5.0	5.0	No
15	Pond A	50	10	8	5.0	5.0	Yes
16	Pond A	50	50	8	5.0	5.0	No
17	Pond A	90	50	8	5.0	5.0	No
18	Pond A	90	50	8	10.0	5.0	No
19	Pond A	90	50	8	10.0	0.0	No
20	Pond A	90	20	8	10.0	0.0	No
21A	Pond A	50	20	24	5.0	1.0	No
21B[2]	Sludge	50	0.6	1	--	--	No
22A	Pond A	50	20	24	5.0	0.0	No
22B[2]	Sludge	50	1.2	1	--	--	No

---

[1]- Core composite tailings sample stored at RPC since 1993 (Oxidized).

[2]- In test B, hydroxide sludge was mixed with filtrate from test A at 25 or 50 ml per liter solution.

Table 2
Leach Test Results (R.T. = 4 hrs)

Test #	Sample ID	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
1	Pond A	17.4	-1.5	13.0	14.0	0.0	14.9	1.8
2	Pond A[1]	43.8	-0.3	64.5	23.6	0.1	35.0	3.3
3	Pond A	18.5	0.2	14.1	16.3	0.0	16.2	0.4
4	Pond A[1]	37.5	0.3	32.0	22.9	0.0	33.6	0.8
5	Pond A	21.7	-0.6	35.4	18.6	0.1	15.6	1.7
6	Pond A	19.7	-0.4	29.4	19.4	0.1	15.6	1.9
7	Pond A	20.4	-0.9	33.0	18.9	0.1	20.3	2.6
8	Pond A	25.8	0.8	41.4	16.5	0.1	22.2	3.2
9	Pond A	17.3	0.0	33.6	18.9	0.0	15.6	1.3
10	Pond A	12.5	0.3	25.5	15.3	0.0	12.9	1.0
11	Pond A	25.8	-1.1	70.3	33.9	0.1	63.6	3.4
12	Pond A	26.2	-0.9	76.6	37.5	0.1	48.1	3.3
13	Pond A	31.2	0.8	81.5	32.8	0.1	67.3	4.8
14	Pond A	31.2	-4.1	73.8	29.3	0.1	73.0	3.7
15	Pond A	31.9	-2.6	85.3	29.0	0.1	93.8	3.4
16	Pond A	28.3	0.9	60.8	32.1	0.0	58.7	2.6
17	Pond A	-0.1	1.2	62.6	25.8	0.0	51.0	4.7
18	Pond A	-0.1	1.5	64.1	28.8	0.0	57.0	5.6
19	Pond A	-0.1	1.9	67.0	31.0	0.0	61.7	5.7
20	Pond A	2.5	2.3	65.6	28.2	0.0	92.0	9.4
21A	Pond A	30.2	1.7	43.2	--	0.0	--	--
21B	Sludge[3]	-2.5	-12.1	48.0	--	7.2	--	--
22A	Pond A	25.1	1.7	41.9	--	0.0	--	--
22B	Sludge[3]	-9.5	-32.3	27.3	--	4.1	--	--

---

[3] - 1 hour leach test

A project review meeting was held in early September and the results of Tests 1 to 20 were discussed. A preliminary process flowsheet option for the mini pilot was designed. The design was to treat pond A tailings with acid mine drainage in an acid leach circuit followed by neutralization with the hydroxide sludge and biosulphide metals recovery. Two final tests were then carried out (Test 21 &22) to evaluate this option. The leach results from these two tests confirmed that the acid leach operating conditions in the mini pilot should be 50°C, 10% slurry density, 5 g/L H_2SO_4 and 0 g/L ferric addition with no aeration (Test 15). The addition of hydroxide sludge after the acid leach resulted in a loss of Cu. Additional tests will thus be required to establish the final flowsheet for the mini pilot operation.

The operational plan calls for a composite feed consisting of a blend from all of the tailings ponds inclusive of B, C, D, E, F, M1, and M2 along with pond A to the leach plant. This composite feed to the leach plant should be evaluated.

Test results at the four hour retention time are presented in Table 2 and detailed results are attached.

If you have any questions or comments, please do not hesitate to contact me by phone at (506) 460-5672 or by Email at rgilders@rpc.unb.ca.

Yours Sincerely,

Ross Gilders

Ross Gilders
Process & Environmental Technology

Project: Metal Extraction Leach Tests on Caribou Mines Anaconda Tailings Sample
Subject: Leach Tests on Fresh Pond A Tailings collected in March 1999 and Core Composite Pond A Tailings

Test # 1 **Date:** Revised July 30, 1999

Conditions:

Fresh Pond A Tailings (Collected in March 1999)

Slurry Density:	20 % w/w
Temperature:	20 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0.5 g/L
Ferric Conc'n:	1 g/L
Aeration:	0 ml/min
Total Solution Volume:	0 8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	--	--	20	30	1128	439	0.86	1.30	1.16	100	0	0	0	0	0	0	0
1	3.55	315	20	827	442	1330	2.99	1.32	3.61	204	20.8	-1.2	17.0	14.7	0.0	16.3	1.8
4	3.42	314	20	695	280	1120	2.88	0.79	3.40	190	17.4	-1.5	13.0	14.0	-0.0	14.9	1.6
24	3.26	327	20	549	102	1060	2.85	2.97	3.19	187	13.5	-1.8	11.9	13.8	0.0	13.5	1.5

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	1.53	22.6	2.09	57.88	1.43	59.96	2.27	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	13.5	-	11.9	13.8	0.0	13.5	1.5
24	Residue	192	20	1.38	24.0	1.92	52	1.49	54	2.33	86.5	100.0	88.1	86.2	100.0	86.5	98.5

Test # 2 **Date:** Revised July 30, 1999

Conditions:

Core Composite Pond A Tailings (Stored at RPC since 1993)

Slurry Density:	20 % w/w
Temperature:	20 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0 5 g/L
Ferric Conc'n:	1 g/L
Aeration:	0 ml/min
Total Solution Volume:	0 8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	--	--	20	30	1128	439	0 86	1.30	1.16	100	0	0	0	0	0	0	0
1	2 8	418	20	2110	955	2540	5 69	1 78	7.71	304	45 6	-0 3	36.9	24 4	0.0	35.5	3 6
4	2 74	390	20	2030	912	4110	5.53	3.83	7.61	288	43.8	-0.3	64 5	23 6	0.1	35 0	3.3
24	2 67	349	20	2120	834	2330	5 33	3 91	7 70	308	45 8	-0.5	33.2	22 6	0 1	35.5	3.7

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	1 83	25 81	2 28	79 25	1 63	73 79	2 24	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	45 8	--	33.2	22 6	0 1	35 5	3.7
24	Residue	183 2	20	1 08	28 3	1 66	67	1 78	52	2 36	54 2	--	66 8	77 4	99 9	64 5	96 3

Test # 3 Date: **Revised July 30, 1999**

Conditions:

Fresh Pond A Tailings
Slurry Density: 20 **% w/w**
Temperature: 20 **°C**
AMD Concentration: **Head Solution Assays**
pH: Adjusted to be the same as Test #4
Ferric Conc'n: 0 **g/L**
Aeration: 0 **ml/min**
Total Solution Volume: 0.8 **L**

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Total Acid Added (ml)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	2.16	590	0	30	128	439	0.86	1.30	1.16	100	0	0	0	0	0	0	0
1	3.39-3.10	319	0.8	1060	251	1300	2.97	2.90	3.38	180	21.1	0.2	18.4	18.7	0.0	18.3	0.6
4	3.15-3.09	328	1.5	931	228	1100	2.70	2.60	3.12	157	18.5	0.2	14.1	16.3	0.0	16.2	0.4

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	1.95	19.90	1.87	45.18	2.42	48.50	5.14	100	100	100	100	100	100	100
4	Sol'n	--	--	--	--	--	--	--	--	--	18.5	0.2	14.1	16.3	0.0	16.2	0.4
4	Residue	189.1	20	1.68	21	1.7	40	2.56	43	5.41	81.5	99.8	85.9	83.7	100.0	83.8	99.6

Test # 4

Date: **Revised July 30, 1999**

Conditions:

Core Composite Pond A Tailings (Stored at RPC since 1993)
Slurry Density: 20 **% w/w**
Temperature: 20 **°C**
AMD Concentration: **Head Solution Assays**
H2SO4 Conc'n: 0.5 **g/L**
Ferric Conc'n: 0 **g/L**
Aeration: 0 **ml/min**
Total Solution Volume: 0.8 **L**

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Total Acid Added (ml)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	2.16	590	0	30	128	439	0.86	1.30	1.16	100	0	0	0	0	0	0	0
1	3.10	362	0	2020	327	2250	5.26	0.14	6.46	170	38.7	0.3	34.6	25.2	-0.0	37.6	1.2
4	3.09	343	0	1960	305	2110	4.86	0.21	5.90	145	37.5	0.3	32.0	22.9	-0.0	33.6	0.8

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	2.06	24.51	2.09	69.81	1.54	56.35	2.41	100	100	100	100	100	100	100
4	Sol'n	--	--	--	--	--	--	--	--	--	37.5	0.3	32.0	22.9	--	33.6	0.8
4	Residue	182.4	20	1.41	26.8	1.56	59	1.69	41	2.62	62.5	99.7	68.0	77.1	100.0	66.4	99.2

Project: Metals Extraction Leach Tests on Caribou Mines Anaconda Tailings Sample
Subject: Leach Tests on Fresh Pond A Tailings collected in May 1999

Test # 5 Date: 08/06/1999 Revised on July 30, 1999

Conditions:

Fresh Pond A Tailings
Slurry Density: 20 % w/w
Temperature: 20 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 0.5 g/L
Ferric Conc'n: ~ 1 g/L
Total Solution Volume: 0.8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	--	--	20	30.3	1151	518	0.965	1.31	1.27	93	0	0	0	0	0	0	0
1	2.54	416	20	925	909	2490	5.08	2.78	6.58	169	20.3	-0.5	34.2	18.7	0.0	15.4	1.5
4	2.78	392	20	987	857	2560	5.05	4.16	6.68	181	21.7	-0.6	35.4	18.6	0.1	15.6	1.7
24	2.75	356	20	1020	864	2680	5.08	4.5	7.08	191	22.5	-0.5	37.5	18.7	0.1	16.8	1.9

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	184.19	20	1.91	23.2	2.51	95.44	2.47	150.17	2.20	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	22.5	-	37.5	18.7	0.1	16.8	1.9
24	Residue	171.73	20	1.59	25.0	1.68	83.2	2.65	134	2.31	77.5	100.0	62.5	81.3	99.9	83.2	98.1

Test # 6 Date: 08/06/1999 Revised on July 30, 1999

Conditions:

Fresh Pond A Tailings
Slurry Density: 10 % w/w
Temperature: 20 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 0.5 g/L
Ferric Conc'n: ~ 1 g/L
Total Solution Volume: 0.8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	--	--	20	30.3	1151	518	0.965	1.31	1.27	93	0	0	0	0	0	0	0
1	2.34	441	20	477	1070	1520	3.27	4.29	4.09	139	19.3	-0.3	30.0	20.7	0.1	16.6	1.8
4	2.49	424	20	487	1040	1500	3.12	3.18	3.92	140	19.7	-0.4	29.4	19.4	0.1	15.6	1.9
24	2.34	379	20	692	1390	2050	4.18	4.8	5.22	197	28.6	0.9	45.8	28.9	0.1	23.3	4.1

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	81.87	20	2.26	25.7	3.27	108.79	2.60	165.80	2.46	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	28.6	-	45.8	28.9	0.1	23.3	4.1
24	Residue	78.3	20	1.69	26.6	1.85	80.9	2.71	133	2.47	71.4	100.0	54.2	71.1	99.9	76.7	95.9

Test # 7 Date: 13/06/1999 Revised on July 30, 1999

Conditions:

Fresh Pond A Tailings	
Slurry Density:	20 % w/w
Temperature:	20 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0 g/L
Ferric Conc'n:	~ 1 g/L
Total Solution Volume:	0.8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	2.39	656	20	30.3	1151	518	0.965	1.31	1.27	93	0	0	0	0	0	0	0
1	2.77	401	20	1040	913	TBA	6.37	4.74	7.69	184	24.9	-0.5	-9.0	24.9	0.1	17.9	2.1
4	2.8	360	20	857	732	2420	5.07	4.48	6.70	155	20.4	-0.9	33.0	18.9	0.1	15.2	1.5
24	2.86	346	20	1120	777	3190	5.08	5.55	8.52	206	26.9	-0.8	46.3	18.9	0.1	20.3	2.6

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	1.62	18.70	2.31	86.97	1.96	143.13	1.71	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	26.9	-	46.3	18.9	0.1	20.3	2.6
24	Residue	176.95	20	1.34	21.3	1.4	79.7	2.21	129	1.88	73.1	100.0	53.7	81.1	99.9	79.7	97.4

Test # 8 Date: 13/06/1999 Revised on July 30, 1999

Conditions:

Fresh Pond A Tailings	
Slurry Density:	20 % w/w
Temperature:	20 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	5 g/L
Ferric Conc'n:	~ 1 g/L
Total Solution Volume:	0.8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.37	663	20	30.3	1151	518	0.965	1.31	1.27	93	0	0	0	0	0	0	0
1	1.82	416	20	918	1160	2330	4.94	5.57	7.05	184	19.3	0.0	29.5	16.0	0.1	15.6	2.0
4	1.78	398	20	1220	1540	3060	5.07	7.26	9.51	242	25.8	0.8	41.4	16.5	0.1	22.2	3.2
24	1.92	366	20	1460	1850	3290	6.97	7.88	10.59	287	31.0	1.4	45.1	24.1	0.1	25.1	4.2

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	1.84	19.31	2.46	99.60	2.02	148.63	1.86	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	31.0	-	45.1	24.1	0.1	25.1	4.2
24	Residue	175.35	20	1.45	21.7	1.54	86.2	2.30	127	2.03	69.0	100.0	54.9	75.9	99.9	74.9	95.8

Test # 9 **Date:** **14/06/1999** **Revised on July 30, 1999**

Conditions:

Fresh Pond A Tailings	
Slurry Density:	20 % w/w
Temperature:	20 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0.5 g/L
Ferric Conc'n:	0 g/L
Total Solution Volume:	0.8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	2.28	620	20	30.3	151	518	0.965	1.31	1.27	93	0	0	0	0	0	0	0
1	2.82	343	20	847	185	2860	5.06	4.4	7.42	168	19.1	0.1	41.2	18.8	0.1	17.5	1.7
4	3.16	340	20	768	141	2430	5.07	3.87	6.78	151	17.3	-0.0	33.6	18.9	0.0	15.6	1.3
24	3.18	340	20	971	93.5	2720	5.09	4.07	7.92	187	22.0	-0.1	38.7	19.0	0.1	18.9	2.1

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	20	1.71	20.15	2.28	86.99	2.16	140.91	1.81	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	22.0	-	38.7	19.0	0.1	18.9	2.1
24	Residue	173.2	20	1.54	23.3	1.61	81.4	2.49	132	2.05	78.0	100.0	61.3	81.0	99.9	81.1	97.9

Test # 10 **Date:** **14/06/1999** **Revised on July 30, 1999**

Conditions:

Fresh Pond A Tailings	
Slurry Density:	50 % w/w
Temperature:	20 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0.5 g/L
Ferric Conc'n:	1 g/L
Total Solution Volume:	0.8 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	2.21	658	20	30.3	1151	518	0.965	1.31	1.27	93	0	0	0	0	0	0	0
1	3.15	338	20	2970	686	8210	19.3	7.82	24.4	359	16.2	0.2	32.2	20.2	0.0	16.4	1.3
4	3.2	341	20	2290	380	6620	14.9	6.53	19.50	293	12.5	0.3	25.5	15.3	0.0	12.9	1.0
24	2.96	345	20	3120	182	8940	20.2	9.16	26	422	17.0	0.4	35.3	21.2	0.0	17.5	1.6

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	800	20	1.81	22.80	2.39	90.90	2.33	140.97	2.01	100	100	100	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	--	--	17.0	-	35.3	21.2	0.0	17.5	1.6
24	Residue	699.16	20	1.72	26.2	1.77	82	2.67	133	2.26	83.0	100.0	64.7	78.8	100.0	17.5	98.4

Project: Metal Extraction Leach Tests on Caribou Mines Anaconda Tailings Sample
Subject: Leach Tests on Fresh Pond A Tailings collected in May 1999

Test # 11 Date: 15/07/1999

Conditions:

Fresh Pond A Tailings	
Slurry Density:	10 % w/w
Temperature:	50 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0.5 g/L
Ferric Conc'n:	1 g/L
Aeration:	0 ml/min
Total Solution Volume:	1.2 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.8	674	50	37.5	1178	518	0.81	1.10	1.2	104	0	0	0	0	0	0	0
1	1.98	361	50	619	995	2180	3.66	3.71	6.2	186	26.6	-0.7	73.4	36.9	0.1	69.1	3.5
4	2.03	334	50	601	912	2110	3.43	2.93	5.80	184	25.8	-1.1	70.3	33.9	0.1	63.6	3.4
8	2	338	50	525	758	1878	3.41	1	5.42	179	22.3	-1.7	60.1	33.6	-0.0	58.3	3.2

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	133.33	50	1.97	22.2	2.04	69.54	2.24	65.12	2.11	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	22.3	-	60.1	33.6	-0.0	58.3	3.2
8	Residue	120.63	50	1.69	25.0	0.9	51	2.48	30	2.26	77.7	100.0	39.9	66.4	100.0	41.7	96.8

Test # 12 Date: 15/07/1999

Conditions:

Fresh Pond A Tailings	
Slurry Density:	10 % w/w
Temperature:	50 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	0.5 g/L
Ferric Conc'n:	1 g/L
Aeration:	3628 ml/min
Total Solution Volume:	1.2 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.79	672	50	37.5	1178	518	0.81	1.10	1.2	104	0	0	0	0	0	0	0
1	1.84	367	50	613	1040	2270	3.52	4.1	5.8	178	27.2	-0.6	77.0	40.8	0.1	52.7	3.2
4	1.91	337	50	593	980	2260	3.3	3.78	5.40	182	26.2	-0.9	76.6	37.5	0.1	48.1	3.3
8	1.81	338	50	537	782	2064	2.76	2.96	5.93	160	23.6	-1.7	68.0	29.4	0.1	54.2	2.4

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	133.33	50	1.91	20.85	2.05	59.79	1.86	78.52	2.11	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	23.6	--	68.0	29.4	0.1	54.2	2.4
8	Residue	119.82	50	1.62	23.6	0.73	47	2.07	40	2.29	76.4	--	32.0	70.6	99.9	45.8	97.6

Test # 13 **Date:** **15/07/1999**

Conditions:

Fresh Pond A Tailings
Slurry Density: 10 % w/w
Temperature: 50 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 5 g/L
Ferric Conc'n: ~1 g/L
Aeration: 0 ml/min
Total Solution Volume: 1.2 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.3	683	50	37.5	1178	518	0.81	1.10	1.2	104	0	0	0	0	0	0	0
1	1.24	374	50	630	1280	2270	2.93	4.3	6.4	194	25.5	0.4	74.3	30.0	0.1	64.8	3.9
4	1.31	353	50	764	1370	2440	3.13	4.13	6.60	216	31.2	0.8	81.5	32.8	0.1	67.3	4.8
8	1.47	344	50	780	1363	2084	2.87	4.12	6.21	208	31.9	0.7	66.4	29.1	0.1	62.5	4.5

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	133.33	50	2.10	22.56	2.12	63.69	2.16	72.18	2.09	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	31.9	0.7	66.4	29.1	0.1	62.5	4.5
8	Residue	120.4	50	1.58	24.8	0.79	50	2.39	30	2.21	68.1	99.3	33.6	70.9	99.9	37.5	95.5

Test # 14 **Date:** **15/07/1999**

Conditions:

Fresh Pond A Tailings
Slurry Density: 10 % w/w
Temperature: 50 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 5 g/L
Ferric Conc'n: ~5 g/L
Aeration: 0 ml/min
Total Solution Volume: 1.2 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.18	664	50	37.5	5178	518	0.81	1.10	1.2	104	0	0	0	0	0	0	0
1	1.25	441	50	610	4390	2120	2.63	3.74	6.2	190	25.2	-3.3	59.0	29.0	0.1	65.2	3.7
4	1.1	406	50	748	4190	2520	2.85	4.69	6.80	190	31.2	-4.1	73.8	29.3	0.1	73.0	3.7
8	1.24	360	50	929	4465	2848	2.83	4.66	6.85	199	39.2	-3.0	85.9	29.0	0.1	73.7	4.0

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	133.33	50	2.05	21.72	2.44	62.72	1.90	69.03	2.11	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	39.2	--	85.9	29.0	0.1	73.7	4.0
8	Residue	121.19	50	1.37	24.6	0.38	49	2.09	20	2.23	60.8	--	14.1	71.0	99.9	26.3	96.0

Test # 15 Date: 15/07/1999

Conditions:

Fresh Pond A Tailings
Slurry Density: 10 % w/w
Temperature: 50 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 5 g/L
Ferric Conc'n: 5 g/L
Aeration: 3628 ml/min
Total Solution Volume: 1.2 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.17	667	50	37.5	5178	518	0.81	1.10	1.2	104	0	0	0	0	0	0	0
1	1.24	442	50	626	4730	2110	2.82	3.75	6.8	184	26.0	-1.9	72.6	28.7	0.1	82.1	3.4
4	1.08	408	50	758	4570	2390	2.84	3.85	7.60	184	31.9	-2.6	85.3	29.0	0.1	93.8	3.4
8	1.19	364	50	913	4398	2348	2.76	4.89	7.01	187	38.7	-3.3	83.4	27.9	0.2	85.2	3.5

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	133.33	50	2.03	21.30	1.97	63.01	2.24	61.38	2.14	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	38.7	--	83.4	27.9	0.2	85.2	3.5
8	Residue	121.22	50	1.37	24.2	0.36	50	2.46	10	2.27	61.3	--	16.6	72.1	99.8	14.8	96.5

Project: Me. -xtraction Leach Tests on Caribou Mines Anaconda Tailings Sample
Subject: Leach Tests on Fresh Pond A Tailings collected in May 1999

Test # 16 **Date:** 10/08/1999

Conditions:

Fresh Pond A Tailings	
Slurry Density:	50 % w/w
Temperature:	50 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	5.0 g/L
Ferric Conc'n:	5.0 g/L
Aeration:	0 ml/min
Total Solution Volume:	0.5 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.55	712	50	22.2	3100	500	0.80	1.18	1.1	117	0.0	0.0	0.0	0.0	0.00	0.0	0.0
1	1.85	353	50	5000	4920	17400	22	5.33	43	670	27.2	0.8	58.4	30.7	0.02	60.2	2.2
2	1.90	341	50	4830	4750	16800	21	4.08	40	680	26.3	0.7	56.3	29.2	0.01	55.9	2.2
4	2.03	330	50	5200	5240	18100	23	4.84	42	790	28.3	0.9	60.8	32.1	0.01	58.7	2.6
8	2.50	331	50	4740	4750	17600	20	4.76	43	900	25.8	0.7	59.1	27.8	0.01	60.2	3.1

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	500	50	1.83	23.7	2.89	69.1	2.61	69.6	2.56	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	25.8	0.7	59.1	27.8	0.01	60.2	3.1
8	Residue	462.1	50	1.47	25.5	1.28	54	2.82	30	2.69	74.2	99.3	40.9	72.2	100.0	39.8	96.9

Test # 17 **Date:** 11/08/1999

Conditions:

Fresh Pond A Tailings	
Slurry Density:	50 % w/w
Temperature:	90 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	5.0 g/L
Ferric Conc'n:	5.0 g/L
Aeration:	0 ml/min
Total Solution Volume:	0.5 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.55	685	90	22.2	3100	500	0.80	1.18	1.1	117	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.75	338	90	1790	4440	15700	20	5.49	37	860	10.1	0.6	62.6	30.6	0.02	51.0	3.0
2	1.80	285	90	84	5600	17800	20	4.11	42	1390	0.4	1.1	71.2	30.6	0.02	58.1	5.1
4	2.20	215	90	1.46	6030	15700	17	1.50	37	1290	-0.1	1.2	62.6	25.8	0.00	51.0	4.7
8	1.84	207	90	0.67	6430	15800	19	0.34	46	1300	-0.1	1.4	63.0	29.0	-0.00	63.8	4.7

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	500	90	1.75	23.6	2.43	62.7	1.82	70.3	2.52	100	100	100	100	100	100	100
8	Sol'n	--	--	--	--	--	--	--	--	--	-	1.4	63.0	29.0	-0.00	63.8	4.7
8	Residue	454.3	90	1.93	25.6	0.99	49	2	28	2.64	100.0	98.6	37.0	71.0	100.0	36.2	95.3

Test # 18 Date: 11/08/1999

Conditions:

Fresh Pond A Tailings
Slurry Density: 50 % w/w
Temperature: 90 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 10.0 g/L
Ferric Conc'n: 5.0 g/L
Aeration: 0 ml/min
Total Solution Volume: 0.5 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.40	695	90	22.2	3100	500	0.80	1.18	1.1	117	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.65	331	90	2590	5100	16100	20	5.24	40	950	14.8	0.9	62.9	30.4	0.03	54.2	3.3
2	1.82	307	90	319	5410	16000	17	4.04	39	1300	1.7	1.0	62.5	25.7	0.02	52.8	4.8
4	2.02	228	90	6.15	6570	16400	19	3.51	42	1510	-0.1	1.5	64.1	28.8	0.02	57.0	5.6
8	1.66	201	90	0.48	7240	16700	20	1.03	46	1540	-0.1	1.8	65.3	30.4	-0.00	62.5	5.7

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	500	90	1.74	23.18	2.48	63.12	1.50	71.79	2.49	100	100	100	100	100	100	100
8	Sol'n			--	--	--	--	--	--	--	-	1.8	65.3	30.4	-0.0	62.5	5.7
8	Residue	448.1		1.94	25.4	0.96	49	1.67	30	2.62	100.0	98.2	34.7	69.6	100.0	37.5	94.3

Test # 19 Date: 13/08/1999

Conditions:

Fresh Pond A Tailings
Slurry Density: 50 % w/w
Temperature: 90 °C
AMD Concentration: Head Solution Assays
H2SO4 Conc'n: 10.0 g/L
Ferric Conc'n: 0.0 g/L
Aeration: 0 ml/min
Total Solution Volume: 0.5 L

Solution

		Assays									Extraction						
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	1.73	600	90	22.2	96.5	500	0.80	1.18	1.1	117	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.95	252	90	15.0	3040	17500	21	3.84	41	1250	-0.04	1.2	60.3	29.5	0.01	49.3	4.6
2	2.10	227	90	5.06	3250	16700	20	4.39	40	1330	-0.10	1.3	57.4	28.1	0.01	48.1	5.0
4	2.34	193	90	4.72	4680	19400	22	4.76	51	1510	-0.10	1.9	67.0	31.0	0.01	61.7	5.7
8	2.32	183	90	0.37	5000	19000	22	4.95	53	1360	-0.13	2.1	65.6	31.0	0.02	64.1	5.1

Solids Assays

		Assays									Distribution						
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	500	90	1.74	23.63	2.82	68.4	2.47	80.9	2.45	100	100	100	100	100	100	100
8	Sol'n			--	--	--	--	--	--	--	-	2.1	65.6	31.0	0.0	64.1	5.1
8	Residue	453.7		1.92	25.5	1.07	52	2.72	32	2.56	100.0	97.9	34.4	69.0	100.0	35.9	94.9

Test # 20 **Date:** **13/08/1999**

Conditions:

Fresh Pond A Tailings		
Slurry Density:	20	% w/w
Temperature:	90	°C
AMD Concentration:	Head Solution Assays	
H2SO4 Conc'n:	10.0	g/L
Ferric Conc'n:	0.0	g/L
Aeration:	0	ml/min
Total Solution Volume:	0.8	L

Solution

Total Elapsed Time (hr)	pH	Assays									Extraction						
		ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Co (ppm)	Pb (ppm)	Cd (ppm)	Al (ppm)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	2.03	594	90	22.2	96.5	500	0.80	1.18	1.1	117	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.79	325	90	950	1190	4530	5.46	4.65	10.0	490	21.8	1.9	67.5	31.9	0.06	58.9	6.2
2	1.8	321	90	566	1170	4410	5.22	3.73	9.6	580	12.8	1.9	65.5	30.2	0.04	56.3	7.7
4	1.86	306	90	130	1380	4420	4.92	3.40	15.0	680	2.5	2.3	65.6	28.2	0.04	92.0	9.4
8	1.96	268	90	14	1620	4520	4.80	4.60	11.0	680	-0.2	2.7	67.3	27.4	0.05	65.5	9.4

Solids Assays

Total Elapsed Time (hr)	Sample	Assays									Distribution						
		Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Co (ppm)	Pb (%)	Cd (ppm)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Co (%)	Pb (%)	Cd (%)	Al (%)
0	Head	200	90	1.71	22.72	2.39	58.5	2.51	60.4	2.40	100	100	100	100	100	100	100
8	Sol'n			--	--	--	--	--	--	--	-	2.7	67.3	27.4	0.05	65.5	9.4
8	Residue	173.45	90	1.97	25.5	0.90	49	2.89	24	2.51	100.0	97.3	32.7	72.6	99.9	34.5	90.6

Project: tal Extraction Leach Tests on Caribou Mines Anaconda Tailings Sample
Subject: ach Tests on Fresh Pond A Tailings collected in October 1999

Test # 21A **Date:** 20/10/1999 (Revised on 16/11/1999)

Conditions:

Fresh Pond A Tailings	
Slurry Density:	20 % w/w
Temperature:	50 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	5.0 g/L
Ferric Conc'n:	1.0 g/L
Aeration:	0 ml/min
Total Solution Volume:	1 L

Solution

Total Elapsed Time (hr)	pH	Assays							Extraction			
		ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	SO4 (ppm)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	1.17	597	--	29.3	912	522	1.15	13000	0.0	0.0	0.0	0.0
1	1.89	345	49.5	1330	4920	2450	4.67	19000	29.0	8.9	35.0	0.1
2	1.98	329	50.0	1400	1650	2570	4.65	16000	30.6	1.6	37.2	0.1
4	1.97	320	51.0	1380	1670	2900	4.58	17000	30.2	1.7	43.2	0.0
6	2.01	318	51.0	1390	1580	2800	4.84	16000	30.4	1.5	41.3	0.1
12	2.05	311	52.0	1330	1530	2840	4.92	17000	29.0	1.4	42.1	0.1
24	1.93	316	50.1	1100	1390	2740	5.09	15000	23.9	1.1	40.3	0.1

Solids Assays

Total Elapsed Time (hr)	Sample	Assays							Extraction			
		Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Pb (%)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	Head	250	50	1.79	18.09	2.20	2.79	2.65	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	23.9	1.1	40.3	0.1
24	Residue	231.84	50	1.47	19.3	1.42	3.01	--	76.1	98.9	59.7	99.9

Test # 21B **Date:** 21/10/1999 (Revised on 16/11/1999)

Conditions:

Hydroxide Sludge	
Slurry Density:	25 ml/L of 23A Filtrate
Temperature:	50 °C
Total Solution Volume:	1 L

Solution

Total Elapsed Time (hr)	pH	Assays							Extraction			
		ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	SO4 (ppm)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	1.93	313	48	1110	1220	2280	4.31	13000	0.0	0.0	0.0	0.0
1	3.18	255	50	1082	1072	2680	6.25	13130	-2.5	-12.1	48.0	7.2

Solids Assays

Total Elapsed Time (hr)	Sample	Assays							Extraction			
		Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Pb (%)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	Head	6.071	48	0.11	8.81	13.73	0.44	--	--	--	100	100
1	Sol'n	--	--	--	--	--	--	--	--	--	48.0	7.2
1	Residue	4.708	50	0.74	14.5	9.21	0.53	--	--	--	52.0	92.8

Note: Percentage of copper and iron loss are based on solution head.

Test # 22A Date: 20/10/1999 (Revised on 16/11/1999)

Conditions:

Fresh Pond A Tailings	
Slurry Density:	20 % w/w
Temperature:	50 °C
AMD Concentration:	Head Solution Assays
H2SO4 Conc'n:	5.0 g/L
Ferric Conc'n:	0.0 g/L
Aeration:	0 ml/min
Total Solution Volume:	1 L

Solution

		Assays							Extraction			
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	SO4 (ppm)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	1.19	584	--	28	120	508	1.24	12000	0.0	0.0	0.0	0.0
1	1.99	324	49.5	1270	922	2390	4.82	14000	25.9	1.8	32.6	0.0
2	2.07	319	50.0	1240	928	3060	4.53	15000	25.3	1.8	44.2	0.0
4	2.09	316	51.0	1230	903	2930	4.75	18000	25.1	1.7	41.9	0.0
6	2.09	315	51.0	1230	853	2820	5.17	14000	25.1	1.6	40.0	0.1
12	2.17	310	51.0	1170	808	2890	5.14	16000	23.8	1.5	41.2	0.1
24	2.00	315	50.1	1250	710	2780	5.10	16000	25.5	1.3	39.3	0.1

Solids Assays

		Assays							Extraction			
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Pb (%)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	Head	250	50	1.92	18.26	2.31	2.91	2.65	100	100	100	100
24	Sol'n	--	--	--	--	--	--	--	25.5	1.3	39.3	0.1
24	Residue	233.53	50	1.53	19.30	1.50	3.11	--	74.5	98.7	60.7	99.9

Test # 22B Date: 21/10/1999 (Revised on 16/11/1999)

Conditions:

Hydroxide Sludge	
Slurry Density:	50 ml/L of 24A Filtrate
Temperature:	50 °C
Total Solution Volume:	1 L

Solution

		Assays							Extraction			
Total Elapsed Time (hr)	pH	ORP (mV)	Temp. (deg. C)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Pb (ppm)	SO4 (ppm)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0		311	48.5	985	620	2380	4.30	11500	0.0	0.0	0.0	0.0
1	3.42	241	50	891	420	2753	6.78	11560	-9.5	-32.3	27.3	4.1

Solids Assays

		Assays							Extraction			
Total Elapsed Time (hr)	Sample	Weight (g)	Temp. (deg. C)	Cu (%)	Fe (%)	Zn (%)	Pb (%)	Al (%)	Cu (%)	Fe (%)	Zn (%)	Pb (%)
0	Head	12.142	48.5	0.13	6.85	11.25	0.49	--	--	--	100	100
1	Sol'n			--	--	--	--	--	--	--	27.3	4.1
1	Residue	10.091	50	1.09	10.23	9.84	0.57	--	--	--	72.7	95.9

Note: Percentage of copper and iron loss are based on solution head.

Appendix 4

DRAFT Prefeasibility Study

November 1999

F2

DRAFT

Application of the BioSulphide Process
at
Caribou Mine

Prefeasibility Study

November, 1999

DRAFT

prepared by

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DRAFT

EXECUTIVE SUMMARY

A prefeasibility study was completed to evaluate the potential for commercial application of the BioSulphide Process at Caribou Mine for AMD and Anaconda tailings treatment and concurrent metal recovery. The study was based on existing laboratory data for application at Caribou and on existing BioSulphide data from pilot studies for similar applications.

Following completion of the laboratory scoping testwork, a due diligence site visit was completed in September 1999 to provide site specific information and local costing data to complete a prefeasibility study.

There were four process scenarios included in the study:

Option 1a – treatment of 700 m^3/d AMD only
Option 1b – treatment of 700 m^3/d AMD plus 70 tpd tailings/sludge
Option 2a – treatment of 2,100 m^3/d AMD only
Option 2b – treatment of 2,100 m^3/d AMD plus 210 tpd tailings/sludge

The results of the analysis can be summarized:

	(\$Cdn)			
	Option 1a	**Option 1b**	**Option 2a**	**Option 2b**
Purchased Equipment	911,500	911,500	1,569,750	1,569,750
Construction	1,011,545	1,011,545	1,832,893	1,832,893
Total Capital	**1,923,045**	**1,923,045**	**3,402,643**	**3,402,643**
Annual Operating Cost	391,280	982,580	822,710	2,573,615
Annual Revenue	231,775	1,199,025	732,920	3,567,875
Net Annual Revenue(Cost)	**(159,392)**	**216,317**	**(89,977)**	**994,092**
Annual Lime Savings	145,000	145,000	435,000	435,000
Annual Sludge Savings	unknown	unknown	unknown	unknown
Net Annual Profit (Cost)	**(14,392)**	**361,317**	**345,023**	**1,429,092**

Based on these results it is recommended to proceed with a mini-pilot study at site to provide confirmation of selected design criteria, pilot plant design and operating criteria and process products for downstream testing.

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APPENDIX 1 – Results of Due Diligence Visit

DRAFT

1.0 TERMS OF REFERENCE

The following report is a prefeasibility estimate for commercial application of Biomet's BioSulphide Process to treat acidic drainage and recover valuable base metals and co-products at Caribou Mine in New Brunswick. The estimate is +/- 30% level of accuracy and is based on laboratory testing conducted todate on Caribou samples, previous pilot operating experience on similar treatment processing and cost estimates provided by AGRA Simons Ltd. based on similar projects conducted for Biomet. All of the process design criteria and cost estimates were developed by Biomet for the purpose of in-house valuation of the Caribou project.

The results of this study and the mini-pilot plant operation at site, in progress, will be used to determine if site piloting and an independent project feasibility study is warranted.

1.1 Project Description and Objectives

Based on a site visit to the Caribou Mine in November 1998, and two reports provided by Caribou (RPC and Lorax), a preliminary review of process alternatives to treat acidic mine seepage as well as the Anaconda tailings, stored on site, using the BioSulphide Process was completed. The underlying objective is to treat the Anaconda tailings, including the overlaying sludge, to remove the mobile metals such as Cu, Zn and Pb so that the treated tailings can be deposited with mill tailings in the tailings pond. Co-deposition with lime hydroxide sludge is not a viable option by local regulation. Back-filling the underground mine is not a viable alternative based on discussions with site personnel.

Based on the probable recoverable metal in the Anaconda tailings, it is unlikely that a stand alone BioSulphide plant could be justified. Therefore, the alternatives included treatment plants that could be utilized long term to treat acidic mine drainage, thus eliminating lime treatment and the associated reagent and sludge storage costs. The annual savings in lime consumption was estimated by Caribou Mine personnel at $Cdn145,000 annually. There is no credit assumed for reduction in sludge storage, although this should be considered in more detailed valuations. The annual maintenance cost for the lime circuit and sludge impoundment is not known and was not included in the potential savings.

The treatment objectives considered in developing the process alternatives were:

- Recover Cu and Zn and remove Pb from the mine water (into a Zn concentrate) to help off-set treatment costs and replace the existing lime plant. Also, this would remove these mobile metals from any process sludge and therefore allow sludge deposition with the mill tailings for long term storage, and

- Identify a method to re-treat the hydroxide sludge, overlaying the Anaconda tailings and currently discharged to the pit, to recover Cu and Zn and remove Pb for the reasons above, and
- Incorporate re-treatment of the Anaconda tailings for recovery of soluble Cu and Zn and to remove Pb, again to off-set costs and allow deposition in the tailings pond for long term storage, and
- Minimize capital and operating costs.

Process Alternatives

Case 1 – Acid Mine Drainage Treatment

Case 1 alternative is simply replacing the lime plant with a BioSulphide plant for long term acid water treatment. In this case, a zinc concentrate is produced (approximately 336,000 lb ZnS annually), also containing copper, lead and any cadmium in the drainage. Diesel fuel is used as the nutrient. The BioSulphide product solution is then treated with limestone for iron, aluminum and manganese removal into a high density carbonate sludge for disposal. A small amount of NaHS is produced as a co-product due to excess H_2S produced for process balance.

Case 2 – Add Hydroxide Sludge to Case 1 Flowsheet

Essentially the same flowsheet as Case 1 except the limestone addition is replaced with hydroxide sludge, which increases the recovered ZnS annually, due to contained $ZnSO_4$ in the sludge, and eliminates the limestone costs.

Case 3 – Integrated Processing of AMD and Anaconda Tailings/Sludge

Case 3 is significantly more complex than either Case 1 or Case 2, but has the potential to contribute more to capital repayment if the metal recovery from the tailings is successful. The process requires dissolution of the Anaconda tailings/sludge using both AMD from the property and locally purchased sulphuric acid. The leaching can be carried out at elevated temperatures using waste heat from the BioSulphide Process. The leached tailings are washed for disposal and the resultant leachate is then processed using the BioSulphide Process to recover separate copper and zinc concentrates.

The overlying sludge on the Anaconda tailings contains significant zinc values which can be recovered in the process. However, more sulphate must be reduced due to the increased sulphate from the sludge and sulphuric acid. This results in a significant production of co-product NaHS, for which a local market exists.

The data indicates that there is significant cobalt in the Anaconda tailings and hydroxide sludge. This has not been included as a potential revenue but represents a significant up side to the economics.

Based on previous laboratory testing and preliminary cost estimates, Case 3 showed potential for a net annual revenue from the treatment plant sufficient to repay the initial capital and an ongoing breakeven cost for operation to treat acid mine drainage in the longer term. The tailings re-treatment rate used in the preliminary estimate was 6 years. In addition, the process proposed results in the elimination of the Anaconda tailings/sludge and stored hydroxide sludge as a liability. Once the tailings re-treatment is completed, the BioSulphide plant would have excess capacity to treat the expected AMD flow. Therefore, the general flowsheet for Case 3 was used to complete the prefeasibility study.

Several alternatives using the Case 3 flowsheet were included in the cost analysis:

Option 1 a – treatment of 700 m3/d of AMD only.
Option 1 b – treatment of 700 m3/d of AMD plus 70 tonnes per day of the Anaconda Tailings.
Option 2 a - treatment of the total AMD flow of 2,100 m3/d only.
Option 2 b - treatment of 2,100 m3/d of AMD plus 210 tonnes per day of the Anaconda Tailings.

Capital Costs were derived for only options 1b and 2b, which represent the maximum treatment and thus maximum capital cost for each of the two AMD flow alternatives. Operating costs were estimated for each of the four options, to provide an indication of the ongoing operating costs following tailings re-treatment.

1.2 Laboratory Testwork

Biomet has conducted laboratory scoping testwork using samples of AMD and hydroxide sludge from the site. These data were used, in part, to develop the design criteria for this study. The results are reported under separate cover titled **"The *BioSulphide Process* to Treat AMD and Anaconda Tailings at Caribou Mine – Laboratory Scoping Testwork Final Report"** dated August 1999.

Tailings leach testing was conducted independently by RPC in Fredericton, under the direction of Biomet, to determine the metals leaching characteristics of Pond A Anaconda Tailings. Pond A represents the majority of the Anaconda Tailings stored at site and is the least oxidized, which will require the most aggressive leach conditions to extract the metals. Previous testing had shown that the metals were readily leached from the other Anaconda Ponds under mildly oxidative conditions (reference RPC). The results of the RPC testing up to October 1999 are summarized in the laboratory report referenced above and detailed in the RPC report " **Metals Extraction Leach Tests on Caribou**

Mines Anaconda Tailings and Sludge Composite Samples – Report No. PET/99/341".

1.3 Site Due Diligence

A site visit for due diligence purposes was completed in September 1999, to provide site specific information to complete the prefeasibility study. The primary objectives of the site due diligence was to confirm key process design criteria, site layout and elevations, infrastructure, local costing and local NaHS markets. The results of the site due diligence are included in the process design criteria, flowsheets and cost estimates, Sections 3, 4 and 5/6, respectively.

Project Assumptions

The following assumptions were incorporated into this study and will require confirmation by Biomet or others for feasibility study purposes. Details of the data collected during the due diligence visit and vendor quotations for key consumable items are included in Appendix 1.

Process

Process assumptions that were used in the design criteria and flowsheet development include:

AMD:

- 700 m^3/d nominal flow, annual average
- 2,100 m^3/d maximum flow, annual average
- assays provide by Caribou, average annual values and seasonal fluctuations.

Anaconda Tailings:

- 400,000 tonnes total, including 100,000 tonnes overlaying sludge.
- 206,612 tonnes in Pond A, limited oxidation
- 80,205 tonnes in Pond B, advanced oxidation
- remainder in Ponds C through F and M1/M2

Details of the Anaconda Tailings, supplied by RPC from a previous report, are included in Appendix 1.

Hydroxide Sludge:

- 15,000 m^3 at 5% solids (w/w)

Discharge Criteria:

Copper - 0.3 mg/L
Zinc – 0.2 mg/L

Lead – 0.5 mg/L
pH – 6.5 to 8.5

Receiving Water: 3.6 million m^3 tailings pond, 90 hectares surface area

Consumables

Costs for reagents and local consumables used in this study include (FOB minesite):

Consumable	Type	Supplier	Units	$Cdn/Unit
1. Fuel *	No.2 diesel	Irving	litre	0.29
2. Power *	240 VAC	NB Power	kWh	0.04
3. Lime *	hydrated	Havelock, NB	tonne	128.00
4. Flocculant *	Percol 351	Allied Colloids	kg	4.30
5. Sulphuric Acid	93% sol'n	Noranda-DuPont	tonnes	50.00
6. Limestone	92% $CaCO_3$	Elmtree	tonnes	21.40
7. Gypsum	100% $CaSO_4$	Noranda-DuPont	tonnes	20.00
8. NaOH **	50% sol'n	Van Waters	kg	0.40

* provided by Caribou – Appendix 1
** price used in cost estimates is $Cdn 495/tonne to allow for shipping/handling at site

Labour

The basic labour rate was provided by Caribou Mine at $Cdn 13/hour. This rate was escalated for supervisory and maintenance personnel to $50/h and $26/h, respectively.

NaHS Market

The sale of industrial grade NaHS solution (approx. 38% NaHS) is critical to the process balance to remove excess sulphide and is an important consideration in the project economics. The plant anticipated at Caribou would produce between 0.3 and 3.0 tonnes per day of NaHS (dry weight). Therefore, a local market was identified at the following locations:

1. Tembec, Atholville, NB
2. Fraser Papers Inc., Edmunston, NB
3. St. Anne Nackawic Pulp, Nackawic, NB
4. Repap, Miramichi, NB
5. Stone Container, New Richmond, PQ

The average price paid at the minesite for 38% NaHS is $Cdn 1,050 per tonne of NaHS (dry weight basis). It is likely that the mine will contract the handling and sales of the NaHS product to a local distributor who will provide the onsite storage and handling equipment for the final NaHS product.

Existing Equipment and Infrastructure

Based on the site due diligence visit, there is significant equipment at site, including thickening and filtration, tanks, pumps, reagent systems, piping, electrical and instrumentation that might be incorporated into the BioSulphide Process plant. Also, the mine personnel have process engineering, construction management and construction experience that would probably be utilized to reduce construction overheads for the project. However, the cost estimates included in this study were based on new equipment purchase and contractor installation costs and overheads.

2.0 PROCESS DESCRIPTION

2.1 BioSulphide Process Description

The BIOSULPHIDE PROCESS is an integrated chemical-biological process designed to treat metal-contaminated, sulphate-rich, waste streams. The process has been developed to solve the increasing problem of treatment and disposal of solutions, gases and waste streams that contain heavy metals and sulphate in acidic waste streams. The BIOSULPHIDE PROCESS was developed with the objective of treating these waste streams with concurrent recovery of saleable metal sulphides and sulphide based co-products (eg. NaHS).

Alternative processes available to treat these and related wastes include lime precipitation, lime scrubbing, ion exchange and biosorption, conventional sulphate reduction, and wetlands. In many applications, all of these alternatives encounter technical and/or economic limitations.

The objective in the development of the BIOSULPHIDE PROCESS was to provide a cost effective process to treat acidic sulphate-rich waste streams, that could be easily engineered and operated, using known chemical and biological process steps. The process also needed to produce a saleable grade metal sulphide product and a treated effluent that could be discharged directly to the environment. It was important that the process could be readily integrated into existing operations, without specialized personnel or infrastructure.

The BIOSULPHIDE PROCESS integrates a biological phase and a chemical phase to treat waste water streams to discharge quality and maximum metals recovery. *Essentially, it is a chemical treatment process that uses inexpensive biologically-generated reagents.* The entire stream passes through a chemical treatment stage where the pH is adjusted, using biologically generated alkalinity, and biogenic hydrogen sulphide gas (H_2S) is introduced to selectively precipitate metals from solution as sulphides. The sulphide concentrate(s) are recovered in a dedicated clarifier(s), using a high recirculating load for precipitate seeding and effective flocculation, followed by filtration for final concentrate dewatering.

A predetermined portion of the resultant 'clean' sulphate stream is fed to an anaerobic biological reactor where sulphate is biologically reduced to sulphide (H_2S). The fraction of solution to be treated biologically is normally controlled by the amount of H_2S required for sufficient metal removal. However, a larger portion might be treated if excess alkalinity and/or H_2S is desired for water treatment purposes and/or the production of saleable sulphide-based co-products, such as NaHS, depending on local markets.

The BIOSULPHIDE PROCESS utilizes a mixed anaerobic biological culture to reduce sulphate species already present in the waste water to soluble hydrogen sulphide with the simultaneous production of alkalinity, in the form of carbonate, for pH adjustment. The hydrogen sulphide is stripped into the gas phase and recycled to the chemical treatment step where dissolved metals are selectively precipitated as high grade metal sulphides which can be sold or recycled. Biologically generated alkalinity is also recycled to the chemical treatment step for pH control during selective precipitation. It is important to note that in most cases only a fraction of the total waste sulphate requires treatment to provide hydrogen sulphide sufficient for complete metal removal and pH control. The primary reactions are summarized below:

Chemical Pretreatment:

$M^{2+} + S^{2-} \rightarrow MS$ {where M^{2+} represents a 2+ metal ion}

Biological Reduction:

SO_4^{2-} + Nutrients + $H_2O \rightarrow H_2S + HCO^{3-}$

During the process biomass is continually created. Several nutrient sources have been pilot tested (eg. coal, wood, natural gas combustion products, sewage sludge, glycol and ethanol). For commercial applications, the nutrient source will likely be limited to the combustion products of natural gas, propane or diesel fuel due to the simplicity of operation, high efficiency of nutrient utilization, and because this method provides a heat source for optimum biological activity. In all cases examined to date, excess heat is generated.

The chemical stage retention time is dependent on the number of stages, H_2S concentration in the circulating strip gas, reactor type, clarifier circulating load, and product purity criteria. The chemical stage is typically less than 1 hour total retention time. The biological retention time varies with feed grade and temperature but is typically 20-40 hours.

The BIOSULPHIDE PROCESS is patented. A general process schematic is shown overleaf in Figure 1.

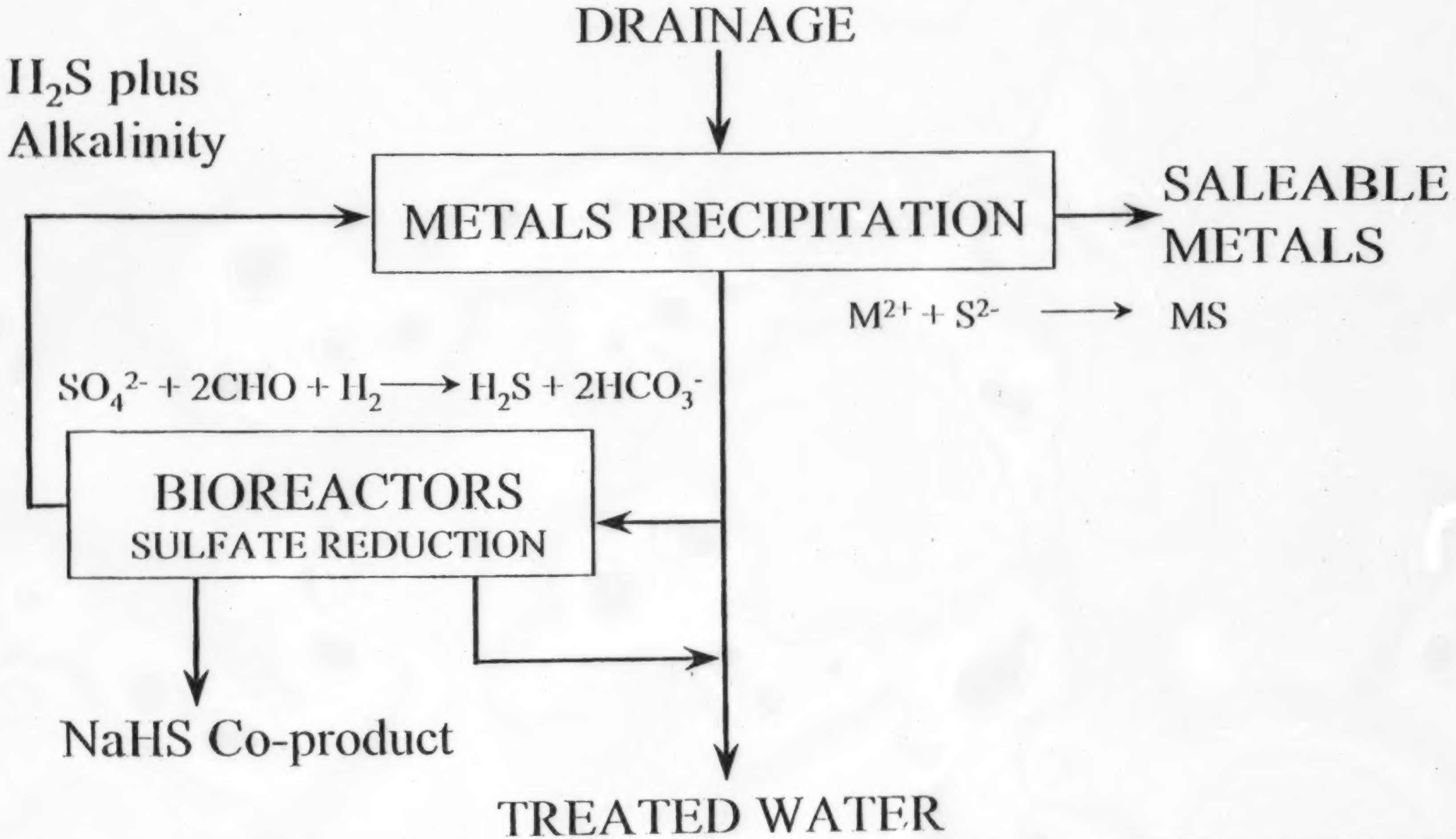
2.2 Caribou Mine Process Description

A general process flowsheet for the Caribou Mine BioSulphide Plant is included overleaf, Figure 2.

The AMD and reclaimed Anaconda Tailings are mixed in an acid leach step to recover acid soluble metals from the tailings. It is assumed that the tailings will be reclaimed as a slurry from the existing storage ponds. Hydroxide sludge, if available, is also leached with the tailings to recover acid soluble metals. Sulphuric acid is added to the leach to provide approximately 5g/L free sulphate. The leach is conducted at >20 C using waste heat from a partial oxidation burner. Following a 4 hour leach, the leached tailings are

Biosulphide Process

Generalized Schematic - Figure 1



DRAINAGE

H_2S plus
Alkalinity

METALS PRECIPITATION

SALEABLE
METALS

$M^{2+} + S^{2-} \longrightarrow MS$

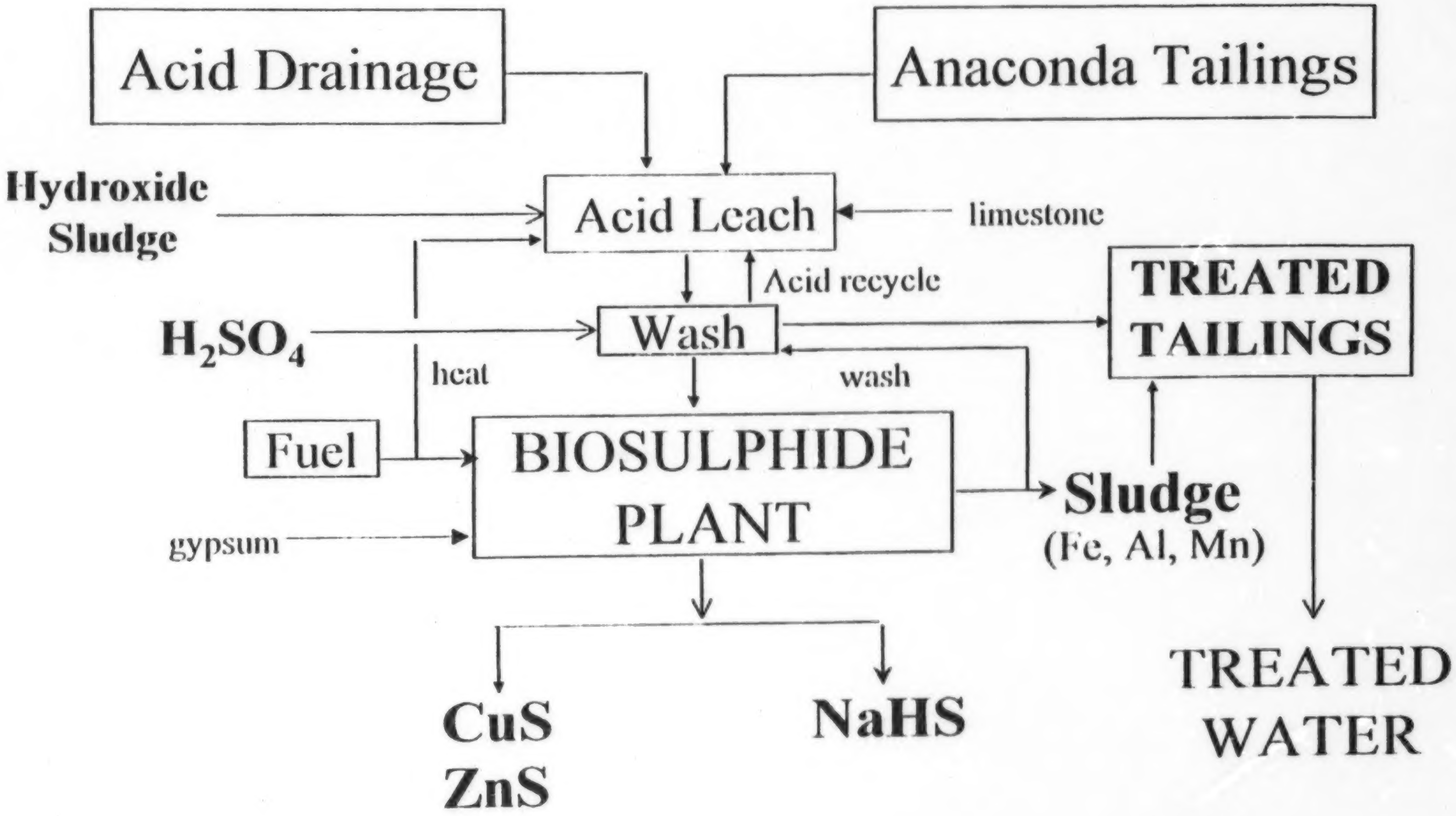
$SO_4^{2-} + 2CHO + H_2 \longrightarrow H_2S + 2HCO_3^-$

BIOREACTORS
SULFATE REDUCTION

NaHS Co-product

TREATED WATER

Figure 2 - Caribou Mine Flowsheet


Acid Drainage
Anaconda Tailings
Hydroxide Sludge
Acid Leach
limestone
Acid recycle
H_2SO_4
Wash
heat
wash
TREATED TAILINGS
Fuel
BIOSULPHIDE PLANT
Sludge
(Fe, Al, Mn)
gypsum
CuS
ZnS
NaHS
TREATED WATER

washed in a thickener, using treated water, and the leach residue sent to tailings using the existing tailings line.

The solution from the leach is mixed with hydroxide sludge and/or limestone for ferric iron removal at a low pH (approx. pH 3), which is an optional step and requires confirmation in additional tailings leaching tests. The sludge from the ferric removal stage is included with the leach residue and sent to tailings. The solution from the leaching circuit, containing the leached metals and AMD, is sent to the BioSulphide circuit.

In the BioSulphide circuit, separate copper and zinc concentrates are produced using biogenic H_2S and alkalinity. Gypsum is added to provide additional sulphate for biological reduction which produces sufficient alkalinity for removal of the remainder of the iron and most of the aluminum and manganese. The iron/aluminum/manganese sludge, at approximately pH 7.5, reports to the final tailings for dewatering.

Diesel fuel is used as the primary nutrient source for the biological sulphate reduction step. Diesel is burned in a partial oxidation burner under controlled conditions to produce a nutrient gas with elevated H_2, CO and CO_2 content, which is readily utilized by the biomass to reduce sulphate. Waste heat is recovered in the partial oxidation burner to heat the bioreactor feed water as well as provide waste heat for tailings leaching, if required.

Excess H_2S is produced which is converted to NaHS using a conventional NaOH scrubbing circuit. The copper and zinc concentrates are sold offsite as well as the NaHS co-product.

Based on continuous process test results so far, the treated water is expected to be at pH 7.5 and contain the following dissolved metals:

Cu - <0.01 mg/L
Zn - 1.0 mg/L
Pb - <0.1 mg/L

3.0 PROCESS DESIGN CRITERIA

The process design criteria that has been used as the basis for this study is provided on the following pages.

LOCATION:

The project is located at the Caribou Mine site near Bathurst, N.B. There is an existing mine operation at the site which is currently shut down for economic reasons. All surface support facilities are currently operational, including acid water collection, treatment and sludge deposition systems. The tailings system is operational and is monitored.

ALTITUDE:

The project is located at approximately 470 m above mean sea level.

ACCESS:

Bathurst is at the crossroads of 4 major routes operated by the New Brunswick Ministry of Highways, Routes 11, 134, 8 and 180 and is serviced by one airport with daily flights to major centers in Canada. Bathurst is serviced by a major railway transport route. The site is located approximately 2 km from Route 180 and is accessed by an all-season service road to the minesite.

DESIGN LIFE:

The nominal design life is 20 years with upgrade anticipated for prolonged operation.

ACID DRAINAGE:

Average flow, m3/d	700
Maximum flow, average daily, m3/d	2,100
Analysis,	
pH	3.0
sulphate, g/L	3.5 g/L
acidity, g/L $CaCO_3$ equiv.	1.7 g/L
Zn, mg/L	400 mg/L
Cu, mg/L	20 mg/L
Fe, mg/L	300 mg/L
Fe3+/Fe2+	1.0
Al, mg/L	150 mg/L
Mn, mg/L	100 mg/L
Pb, mg/L	3 mg/L

ANACONDA TAILINGS LEACH:

Total tonnage, dmt	300,000
Analysis,	
SG	2.85
Zn, %	2.44
Cu, %	2.05
Leaching,	

Leach duration, h	4
Recovery, Zn %	85.9
Cu %	39.2
Acid concentration, g/L H_2SO_4	5
Temperature, C	50
Slurry density, % w/w	10
Pressure. kPa	atm
Thickener U/F, % solids	40
Wash ratio	2
Hydroxide sludge, tonnes	100,000
Density, % solids	5
Alkalinity, mg/L $CaCO_3$ equiv.	960
Analysis,	
Zn, %	9.8
Cu, %	0.6
Fe, %	11.0
Al, %	6.5
Pb, %	0.24

PROCESS PLANT:

Operating Basis, days per year	365
hours per year	8,760
Availability, %	90

PROCESS INPUT:	Option1a	Option1b	Option2a	Option2b
Acid water, m^3/d	700	700	2,100	2,100
Anaconda Tailings, tpd	none	70	none	210
Hydroxide sludge, m^3/d	7	7	21	21
Sulphuric acid, tpd	none	3.6	none	10.9
Limestone, tpd	0.6	0.6	1.7	1.7
Gypsum, tpd	0.7	2.6	0.35	6.0
Diesel fuel, L/d	1,920	5,338	4,272	14,509
NaOH, tpd	0.21	0.72	0.72	2.15
Air, m^3/d (STP)	11,017	30,639	24,419	83,289

PROCESS OUTPUT:

Copper, Cu stage U/F, kg/d	14	443	41	1,300
Zinc, Zn stage U/F, kg/d	271	1,342	812	4,000
NaHS, tpd	0.3	1.0	1.0	3.0
Treated water (pH 7), m^3/d	677	540	2,030	1,600
Leach residue (pH 1.3),				
total solids, tpd	none	65	none	195
$Fe(OH)_3$, kg/d	none	400	none	1,200

$CaSO_4$, kg/d	none	760	none	2,300
tailings, tpd	none	63.7	none	191
slurry vol., m^3/d	none	162	none	490
Iron/gypsum sludge,				
solids, kg/d	1,170	none	3,500	none
slurry vol., m^3/d	24	none	70	none
Off-gas, m_3/d (STP)	6,511	18,108	14,432	49,225

BIOREACTOR:

Biofeed, m^3/d	1100	878	3,050	2630
, % of feed	62	60	62	62
Sulphate, feed, mg/L	1,800	6,000	1,400	5,300
, discharge, mg/L	200	200	200	200
Operating pressure, kPa	atm	atm	atm	atm
Operating temperature, C	30	30	30	30
Mode of operation	cont.	cont.	cont.	cont.
Retention time, h	28	36	26	33
SRR, g/L.d	1.2	3.2	1.1	3.2
SO_4 reduced, tpd	1.52	4.23	3.38	11.56
H_2S production, tpd	0.54	1.5	1.2	4.1
KH_2PO_4, kg/kg SO_4	0.01	0.01	0.01	0.01
$(NH_4)_2SO_4$, kg/kg SO_4	0.1	0.1	0.1	0.1
Overall H_2 utilization, %	60	60	60	60
Bioreactor volume, m^3	1,300	1,300	3,100	3,650
total volume, m^3	1,430	1,430	3,450	4,050

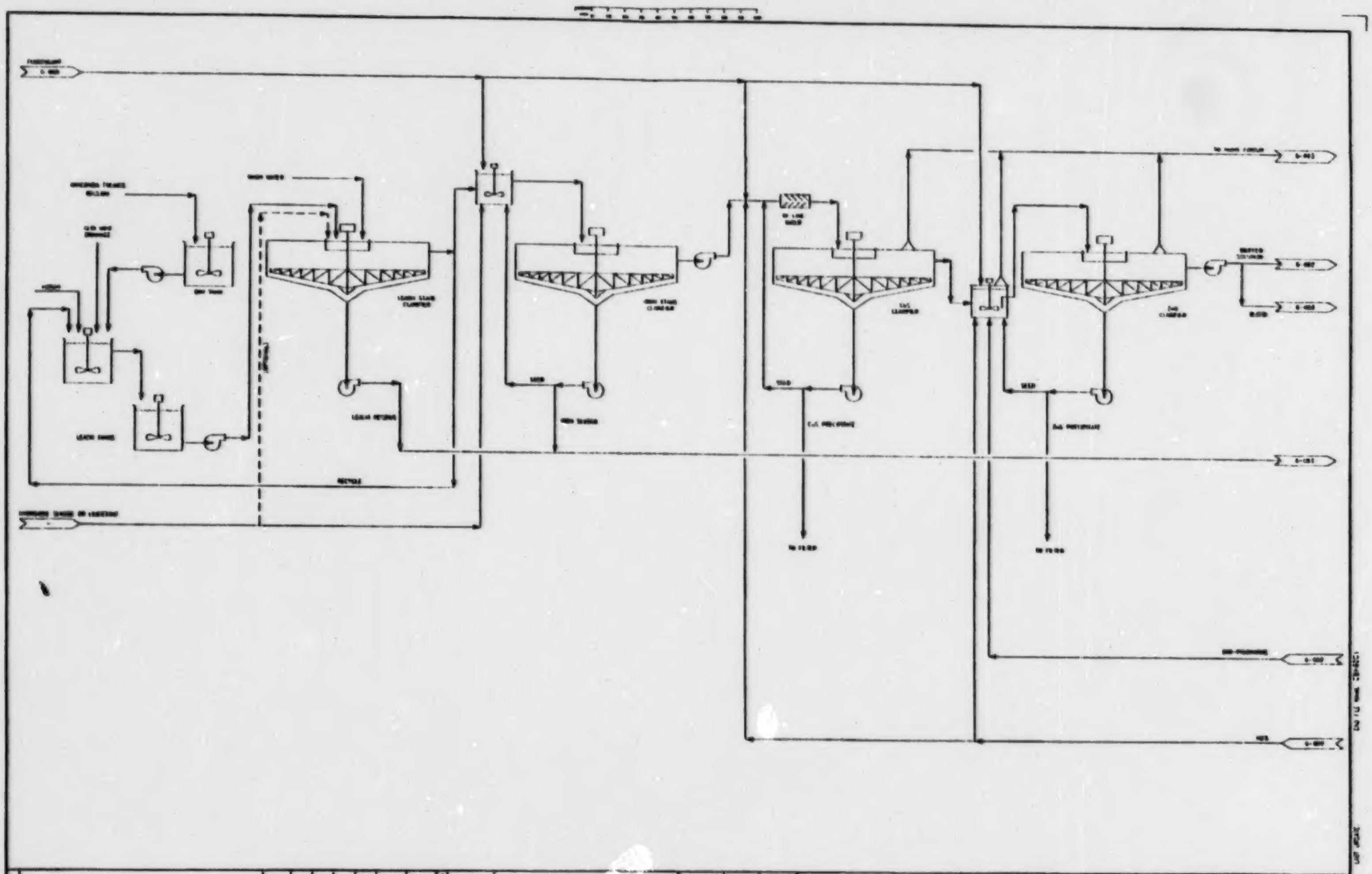
THICKENING/FILTRATION:

Precipitate rise rate, m/h	6	6	6	6
U/F solids, %	40	40	40	40
Seed, % of feed flow	100	100	100	100
Flocculant type	anionic	anionic	anionic	anionic
Flocculant rate, mg/L/stage	5	5	5	5
Bioclarifier rise rate, m/h	1	1	1	1
U/F solids, %	20	20	20	20
Seed, % of feed	100	100	100	100
Batch pressure filter,				
pressure, kPa	1,550	1,550	1,550	1,550
cake moist., %	20	20	20	20
wash ratio	0	0	0	0

4.0 PROCESS FLOWSHEETS

The following process flowsheets are included in this section:

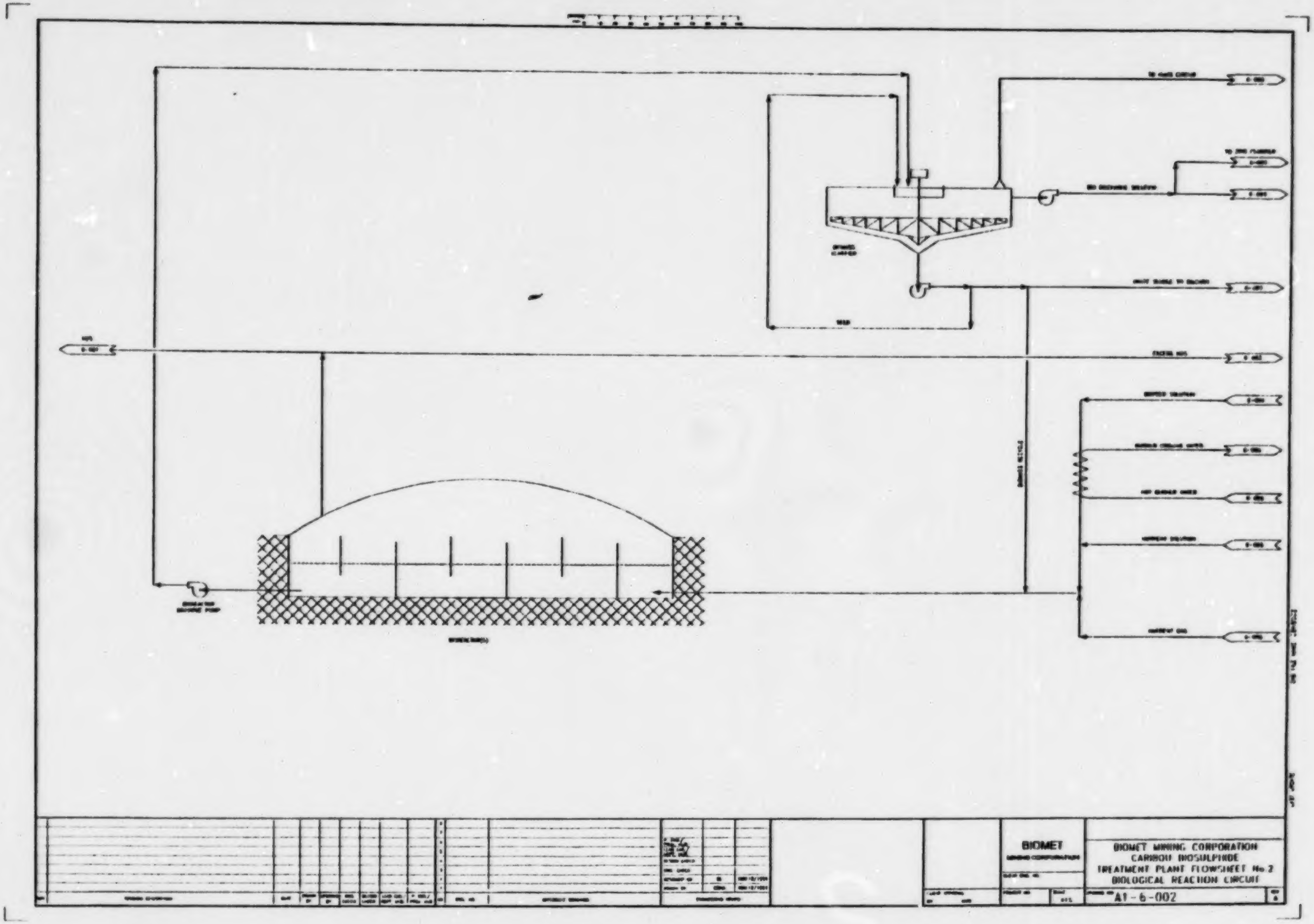
Flowsheet 1 – Precipitation Circuit
Flowsheet 2 – Biological Reaction Circuit
Flowsheet 3 – NaHS Circuit
Flowsheet 4 – Off-gas Scrubbing
Flowsheet 5 – Reagent Systems



BIOMET
MINING CORPORATION

BIOMET MINING CORPORATION
CARIBOU BIOSULPHIDE
TREATMENT PLANT
FLOWSHEET No.1

A1-6-001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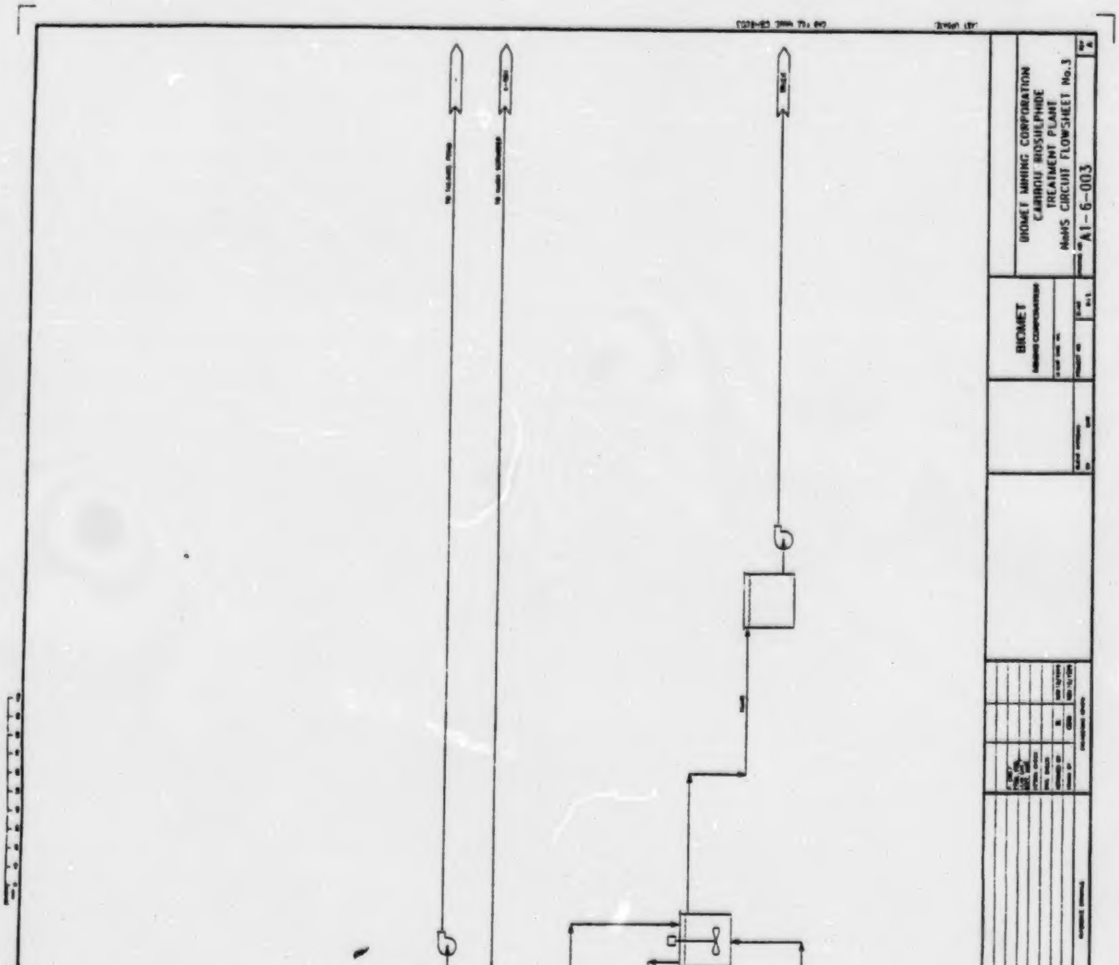
BIOMET MINING CORPORATION
CARIBOU BIOSULPHIDE
TREATMENT PLANT FLOWSHEET No 2
BIOLOGICAL REACTION CIRCUIT
A1-6-002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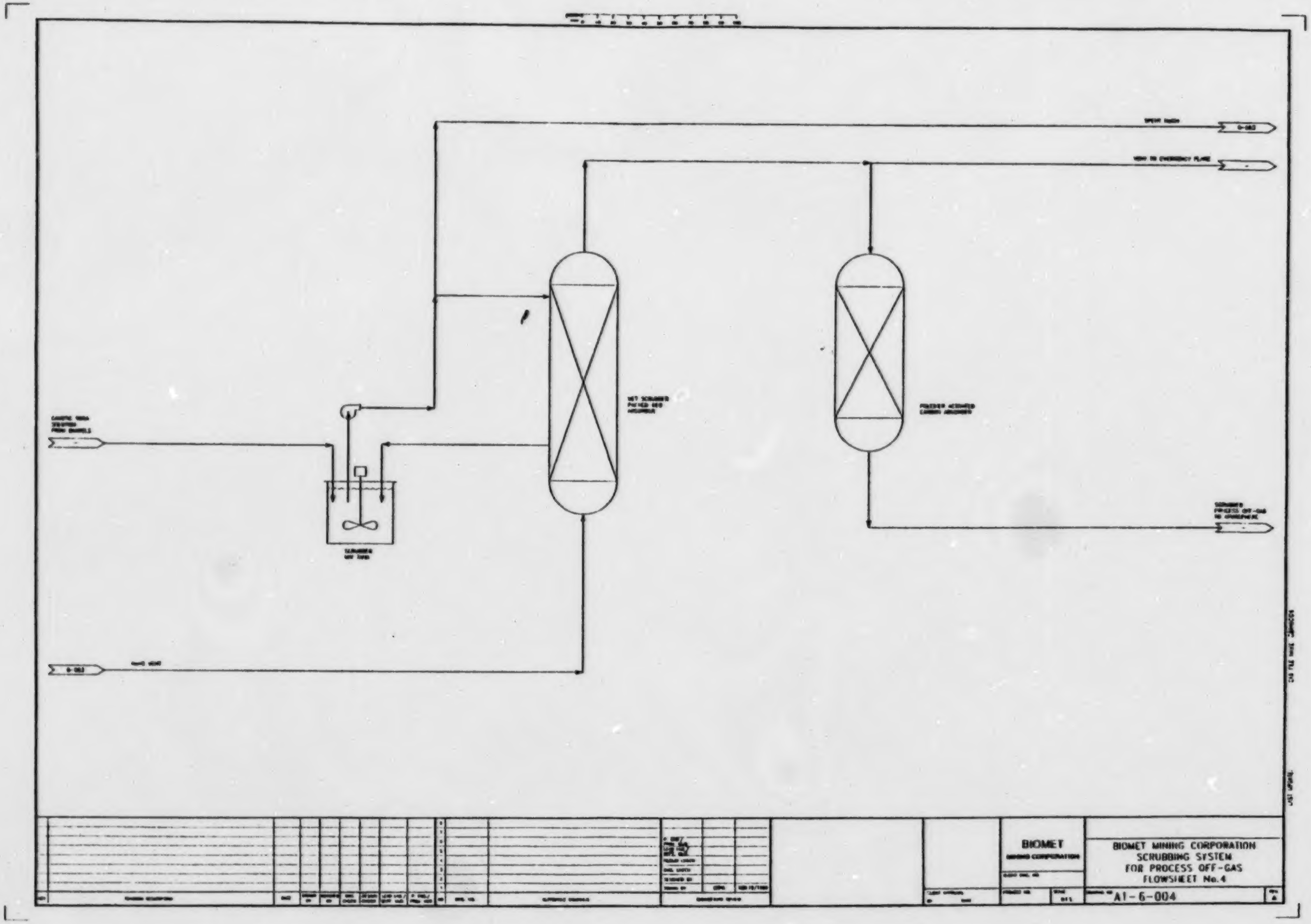
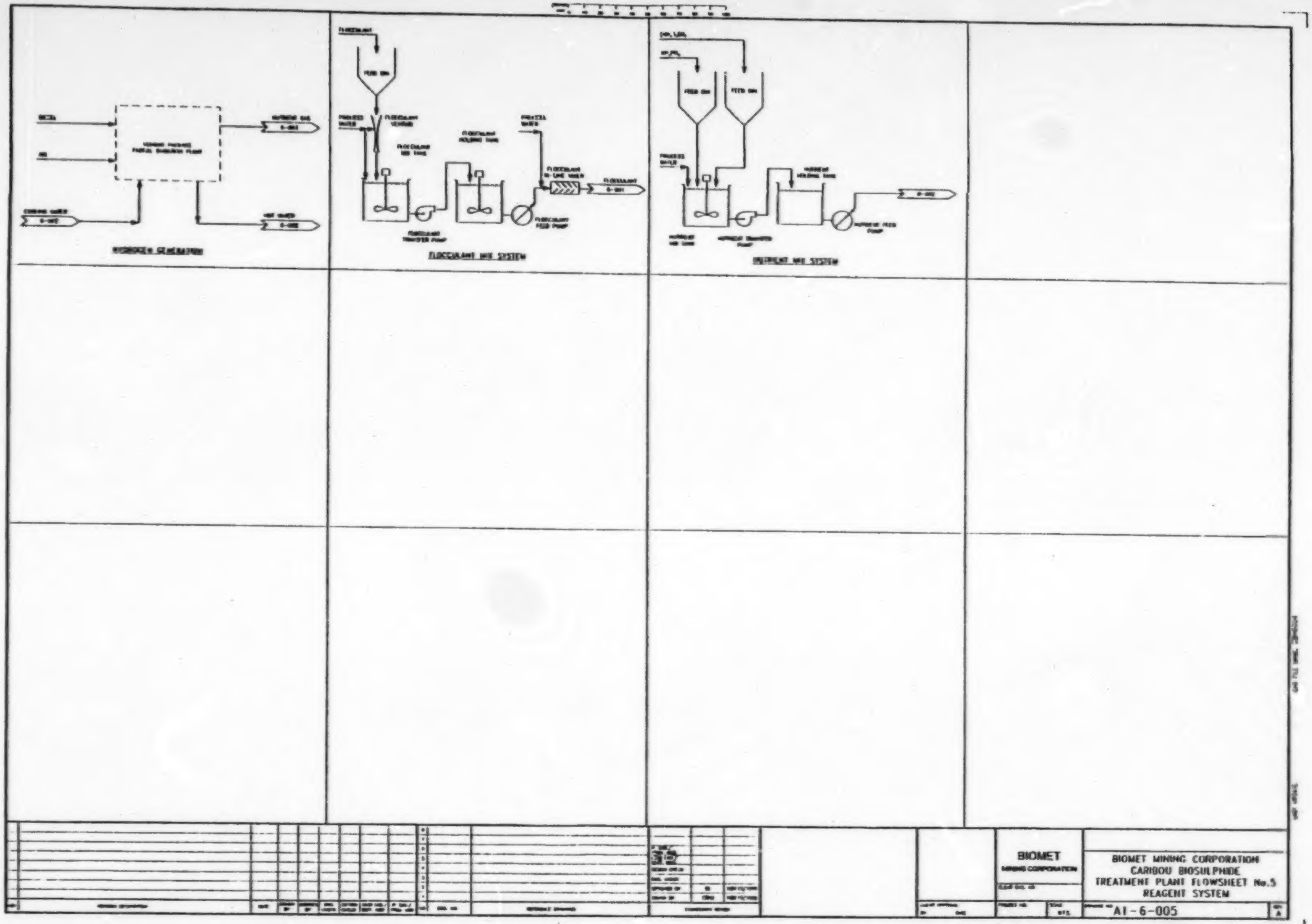
CARIBOU BIOSULPHIDE
TREATMENT PLANT
NaHS CIRCUIT FLOWSHEET No.3
A1-6-003
BIOMET


SPENT WASH
VENT TO EMERGENCY FLARE
WET SCRUBBER PACKED BED ABSORBER
POWDERED ACTIVATED CARBON ADSORBER
SCRUBBED PROCESS OFF-GAS TO ATMOSPHERE
BIOMET
MINING CORPORATION
BIOMET MINING CORPORATION
SCRUBBING SYSTEM
FOR PROCESS OFF-GAS
FLOWSHEET No.4
A1-6-004


HYDROGEN GENERATION
AIR
COOLING WATER
HOT WATER
HYDROGEN GAS
FLOCCULANT MIX SYSTEM
FLOCCULANT
FEED BIN
PROCESS WATER
FLOCCULANT VENTURI
FLOCCULANT MIX TANK
FLOCCULANT HOLDING TANK
FLOCCULANT TRANSFER PUMP
FLOCCULANT FEED PUMP
FLOCCULANT IN-LINE MIXER
NUTRIENT MIX SYSTEM
FEED BIN
FEED BIN
PROCESS WATER
NUTRIENT MIX TANK
NUTRIENT TRANSFER PUMP
NUTRIENT HOLDING TANK
NUTRIENT FEED PUMP

BIOMET
MINING CORPORATION

BIOMET MINING CORPORATION
CARIBOU BIOSULPHIDE
TREATMENT PLANT FLOWSHEET No.5
REAGENT SYSTEM

AI-6-005

5.0 CAPITAL COST ESTIMATES

Capital cost estimates for process options 1b and 2b are detailed in this section. The capital cost for options 1a and 2a would be the same as that for 1b and 2b, respectively.

All costs are shown in $Canadian, unless otherwise specified. The scope of estimate includes the cost of manufacturing, fabrication, and installation of all process equipment and ancillaries, engineering and construction, within the scope and battery limits of the study as shown on the flowsheets in Section 4.0, preceding.

Purchased equipment costs were developed from the equipment list. Equipment costs were based on historical pricing data for similar items, factored for size and capacity as required. Costs for equipment installation, piping, electrical, instrumentation, and buildings were calculated using cost factors related to purchased equipment costs.

A contingency of 15% was applied to all capital costs and a startup working capital allowance of $30,000 included for initial fills.

No details for plant location were derived. It was assumed that the plant would be located in close proximity to available utilities, feed source and infrastructure, as well as being on level ground with sound soil conditions requiring minimum development as foundation.

Excluded from the estimates are:

- Duties and taxes
- Permitting costs
- Owner's costs

Biomet Mining Corporation

Caribou Mine - Base Case 700 m3/d AMD plus 70 tpd Anaconda Tailings Retreatment - Option 1b

ESTIMATE OF MAJOR PLANT EQUIPMENT COSTS

Item No.	Description	HP Req'd /Unit	No. Req'd	Unit Cost ($CDN)	Total Cost ($CDN)
	BIOREACTORS AND BIOLOGICAL CIRCUIT				
1	Bioreactor tanks - 1430 m3 total - 1430 m3 each	-	1	$208,000	$208,000
2	Bioreactor mechanisms	-	1	$10,000	$10,000
3	Biomass clarifier	0.5	1	$65,000	$65,000
4	Biomass return pump	1	2	$3,700	$7,400
5	Bioreactor recycle pumps	3	6	$9,500	$57,000
6	Bioreactor feed/discharge pumps	2	2	$7,500	$15,000
7	Nutrient introduction eductors/venturi, 6 per bioreactor	-	6	$2,500	$15,000
8	Heat exchangers	-	2	$15,000	$30,000
	NUTRIENT SUPPLY SYSTEM				
9	Diesel tank	-	1	$1,000	$1,000
10	Blower, sealed	5	1	$15,000	$15,000
11	N,P,K storage/feeder	0.1	1	$2,600	$2,600
12	N,P,K mix/hold and transfer	1	1	$3,200	$3,200
13	N,P,K metering pump	0.3	1	$2,000	$2,000
	PRECIPITATION CIRCUIT				
14	Rapid mix reactor c/w agitator	0.5	4	$8,000	$32,000
15	Leach tanks c/w agitator	1	3	$11,000	$33,000
16	Transfer pumps	1	3	$5,400	$16,200
17	Reactor/Clarifiers c/w U/F pumps	1	4	$45,000	$180,000
18	Gas strip reactor c/w agitator	1	1	$5,000	$5,000
19	Gas strip blower	5	1	$7,500	$7,500
20	CuS/ZnS product tank c/w mixer/pump	0.5	2	$10,500	$21,000
21	Solution aeration c/w agitator/blower	2	1	$10,000	$10,000
22	Tailings mix tank c/w agitator	2	1	$10,000	$10,000
	BYPASS CIRCUIT				
23	4" eductor	-	1	$2,000	$2,000
24	Automated control valves, AMD flow - large	-	2	$7,500	$15,000
25	Automated control valves, NaHS and floc - small	-	2	$3,500	$7,000
	NaHS circuit				
26	Blower	1	1	$3,600	$3,600
27	Sodium Hyroxide storage/feeder	0.1	1	$2,600	$2,600
28	NaHS rapid mix tank	1	2	$6,000	$12,000
29	NaHS storage tank - vendor supplied	-	1	$0	$0
30	NaHS product pump - vendoe supplied	0.3	1	$0	$0
31	NaHS vent system	1	1	$5,000	$5,000
32	Vent gas scrubber/polishing c/w fan & pump	2	1	$30,000	$30,000
33					
	FLOCCULANT SYSTEM				
34	Flocculant mix unit	3	1	$9,000	$9,000
35	Flocculant metering pumps	0.1	3	$1,400	$4,200
	PRODUCT HANDLING				
36	Sump pumps	0.3	3	$10,000	$30,000
37	Product filter c/w filtrate pump, discharge bin	1	2	$15,000	$30,000
38	Product storage/handling equipment		2	$7,600	$15,200
		36.7			
	TOTAL ESTIMATED MAJOR EQUIPMENT COSTS				**$911,500**

Biomet Mining Corporation

Caribou Mine - Base Case 700 m3/d AMD plus 70 tpd Anaconda Tailings Retreatment

ESTIMATE OF TOTAL PLANT COSTS

Item No.	Description		No. Req'd	Unit Cost ($CDN)	Total Cost ($CDN)
39	**EQUIPMENT INSTALLATION** 15% of estimated major equipment cost	15	-	-	$136,725
40	**PLANT PIPING** 10% of estimated major equipment cost	10	-	-	$91,150
41	**PLANT ELECTRICAL** 10% of estimated major equipment cost	10	-	-	$91,150
42	**PLANT INSTRUMENTATION** 8% of estimated major equipment cost	8	-	-	$72,920
43	**BUILDINGS, STRUCTURES, SITE WORK** 15% of estimated major equipment cost	15	-	-	$136,725
44	**ENGINEERING & CONSTRUCTION** 10% of estimated major equipment cost	10	-	-	$91,150
45	**CONTINGENCY** 15% of estimated major equipment cost	15	-	-	$136,725
46	**PARTIAL OXIDATION BURNER** Vendor package	-	-	-	$225,000
47	**BIOREACTOR MEDIA**	-	-	-	$0
51	**WORKING CAPITAL**				$30,000
	TOTAL ESTIMATED CAPITAL COST OF COMMERCIAL PLANT				**$1,923,045**

Biomet Mining Corporation

Caribou Mine - Expanded Case 2100 m3/d AMD plus 210 tpd Anaconda Tailings Retreatment - Option 2b

ESTIMATE OF MAJOR PLANT EQUIPMENT COSTS

Item No.	Description	HP Req'd /Unit	No. Req'd	Unit Cost ($CDN)	Total Cost ($CDN)
	BIOREACTORS AND BIOLOGICAL CIRCUIT				
1	Bioreactor tanks - 3450 m3 total - 1725 m3 each	-	2	$233,000	$466,000
2	Bioreactor mechanisms	-	2	$11,000	$22,000
3	Biomass clarifier	1	1	$105,000	$105,000
4	Biomass return pump	1	2	$3,700	$7,400
5	Bioreactor recycle pumps	3	12	$9,500	$114,000
6	Bioreactor feed/discharge pumps	5	2	$15,000	$30,000
7	Nutrient introduction eductors/venturi, 6 per bioreactor	-	12	$2,500	$30,000
8	Heat exchangers	-	2	$25,000	$50,000
	NUTRIENT SUPPLY SYSTEM				
9	Diesel tank	-	1	$1,000	$1,000
10	Blower, sealed	5	1	$15,000	$15,000
11	N,P,K storage/feeder	0.1	1	$2,600	$2,600
12	N,P,K mix/hold and transfer	1	1	$3,200	$3,200
13	N,P,K metering pump	0.3	1	$2,000	$2,000
	PRECIPITATION CIRCUIT				
14	Rapid mix reactor c/w agitator	1	4	$15,400	$61,600
15	Leach tanks c/w agitator	2	3	$21,200	$63,600
16	Transfer pumps	2	3	$10,400	$31,200
17	Reactor/Clarifiers c/w U/F pumps	1	4	$65,000	$260,000
18	Gas strip reactor c/w agitator	1	1	$9,650	$9,650
19	Gas strip blower	10	1	$11,400	$11,400
20	CuS/ZnS product tank c/w mixer/pump	1	2	$15,000	$30,000
21	Solution aeration c/w agitator/blower	2	1	$10,000	$10,000
22	Tailings mix tank c/w agitator	3	1	$19,500	$19,500
	BYPASS CIRCUIT				
23	6" eductor	-	1	$3,000	$3,000
24	Automated control valves, AMD flow - large	-	2	$14,500	$29,000
25	Automated control valves, NaHS and floc - small	-	2	$6,800	$13,600
	NaHS circuit				
26	Blower	3	1	$7,000	$7,000
27	Sodium Hyroxide storage/feeder	0.1	1	$2,600	$2,600
28	NaHS rapid mix tank	2	2	$9,000	$18,000
29	NaHS storage tank - vendor supplied	-	1	$0	$0
30	NaHS product pump - vendoe supplied	0.3	1	$0	$0
31	NaHS vent system	1	1	$5,000	$5,000
32	Vent gas scrubber/polishing c/w fan & pump	2	1	$30,000	$30,000
33					
	FLOCCULANT SYSTEM				
34	Flocculant mix unit	3	1	$9,000	$9,000
35	Flocculant metering pumps	0.1	3	$1,400	$4,200
	PRODUCT HANDLING				
36	Sump pumps	0.3	3	$10,000	$30,000
37	Product filter c/w filtrate pump, discharge bin	1	2	$29,000	$58,000
38	Product storage/handling equipment		2	$7,600	$15,200
		52.2			
	TOTAL ESTIMATED MAJOR EQUIPMENT COSTS				**$1,569,750**

Biomet Mining Corporation

Caribou Mine - Expanded Case 2100 m3/d AMD plus 210 tpd Anaconda Tailings Retreatment

ESTIMATE OF TOTAL PLANT COSTS

Item No.	Description		No. Req'd	Unit Cost ($CDN)	Total Cost ($CDN)
39	**EQUIPMENT INSTALLATION** 15% of estimated major equipment cost	15	-	-	$235,463
40	**PLANT PIPING** 10% of estimated major equipment cost	10	-	-	$156,975
41	**PLANT ELECTRICAL** 10% of estimated major equipment cost	10	-	-	$156,975
42	**PLANT INSTRUMENTATION** 8% of estimated major equipment cost	8	-	-	$125,580
43	**BUILDINGS, STRUCTURES, SITE WORK** 15% of estimated major equipment cost	15	-	-	$235,463
44	**ENGINEERING & CONSTRUCTION** 10% of estimated major equipment cost	10	-	-	$156,975
45	**CONTINGENCY** 15% of estimated major equipment cost	15	-	-	$235,463
46	**PARTIAL OXIDATION BURNER** Vendor package	-	-	-	$500,000
47	**BIOREACTOR MEDIA**	-	-	-	$0
51	**WORKING CAPITAL**				$30,000
	TOTAL ESTIMATED CAPITAL COST OF COMMERCIAL PLANT				**$3,402,643**

6.0 OPERATING COST ESTIMATES

The following estimates of operating costs are included:

1. Option 1 a – 700 m^3/d AMD
2. Option 1 b – 700 m^3/d AMD plus 70 tpd tailings
3. Option 2 a – 2,100 m^3/d AMD
4. Option 2 b – 2,100 m^3/d AMD plus 210 tpd tailings

Operating consumable pricing and metal pricing are as shown in the detailed schedules included in this section. Net revenues were estimated for each option, including a $145,000 annual lime savings credit. Excluded from the net revenue estimate is annual savings in lime sludge storage, which is unknown at this time.

Caribou Mine - Base Case 700 m3/d AMD - Option 1a
ESTIMATE OF COMMERCIAL PLANT OPERATING COSTS/REVENUES

Item	Units	Units/day	$/Unit	Total $/day ($CDN)
EXPENSES				
Diesel fuel	L	1920	$0.29	$557
KH2PO4 nutrient	kg	15	$0.28	$4
$(NH_4)SO4$ nutrient	kg	152	$0.41	$62
Flocculant	kg	10.5	$4.30	$45
Caustic (NaOH) @115% stoichiometric	tonnes	0.24	$495	$119
Sulphuric acid	tonnes	0	$50	$0
Limestone	tonnes	0.6	$21	$13
Gypsum	tonnes	0.7	$20	$14
Power:	kWh	1181	$0.04	$47
Maintenance supplies	$/day	-	-	$100
Assays	$/day	-	-	$30
Labour:				
1 Supervisor/Engineer @ 4 hrs/wk x $50/h	$/day			$29
1 Operator @ 28 hrs/wk x $13/hr	$/day	-	-	$52
1 Mech./Elect.@ 10 hrs/wk x $26/h	$/day	-	-	$37
TOTAL DAILY EXPENSES				**$1,072**
REVENUES				
Copper Product: 14 kg/day @ $2.48/kg x 70% NSR	$/day	-	-	$24
Zinc Product: 271 kg/day @ $1.82/kg x 60% NSR	$/day	-	-	$296
NaHS Product 0.3 tonnes/day @ $1050/tonne	$/day	-	-	$315
GROSS DAILY REVENUE				**$635**

NET ANNUAL REVENUE (LOSS)	**($159,392)**
NET ANNUAL LIME SAVINGS	**$145,000**
NET ANNUAL SLUDGE SAVINGS	**$0.00**
NET ANNUAL PROFIT (COST)	**($14,392)**

Caribou Mine - Base Case 700 m3/d AMD plus 70 tpd Anaconda Tailings - Option 1b
ESTIMATE OF COMMERCIAL PLANT OPERATING COSTS/REVENUES

Item	Units	Units/day	$/Unit	Total $/day ($CDN)
EXPENSES				
Diesel fuel	L	5338	$0.29	$1,548
KH2PO4 nutrient	kg	42	$0.28	$12
$(NH_4)SO4$ nutrient	kg	423	$0.41	$173
Flocculant	kg	10.5	$4.30	$45
Caustic (NaOH) @115% stoichiometric	tonnes	0.83	$495	$411
Sulphuric acid	tonnes	3.6	$50	$180
Limestone	tonnes	0.6	$21	$13
Gypsum	tonnes	2.6	$20	$52
Power:	kWh	1181	$0.04	$47
Maintenance supplies	$/day	-	-	$100
Assays	$/day	-	-	$30
Labour:				
1 Supervisor/Engineer @ 4 hrs/wk x $50/h	$/day			$29
1 Operator @ 28 hrs/wk x $13/hr	$/day	-	-	$52
1 Mech./Elect.@ 10 hrs/wk x $26/h	$/day	-	-	$37
TOTAL DAILY EXPENSES				**$2,692**
REVENUES				
Copper Product:				
443 kg/day @ $2.48/kg x 70% NSR	$/day	-	-	$769
Zinc Product:				
1,342 kg/day @ $1.82/kg x 60% NSR	$/day	-	-	$1,465
NaHS Product				
1.0 tonnes/day @ $1050/tonne	$/day	-	-	$1,050
GROSS DAILY REVENUE				**$3,285**

NET ANNUAL REVENUE (LOSS)	**$216,317**
NET ANNUAL LIME SAVINGS	**$145,000**
NET ANNUAL SLUDGE SAVINGS	**$0.00**
NET ANNUAL PROFIT (COST)	**$361,317**

Caribou Mine - Expanded Case 2100 m3/d AMD - Option 2a
ESTIMATE OF COMMERCIAL PLANT OPERATING COSTS/REVENUES

Item	Units	Units/day	$/Unit	Total $/day ($CDN)
EXPENSES				
Diesel fuel	L	4272	$0.29	$1,239
KH2PO4 nutrient	kg	34	$0.28	$10
(NH_4)SO4 nutrient	kg	338	$0.41	$139
Flocculant	kg	31.5	$4.30	$135
Caustic (NaOH) @115% stoichiometric	tonnes	0.83	$495	$411
Sulphuric acid	tonnes	0	$50	$0
Limestone	tonnes	1.7	$21	$36
Gypsum	tonnes	0.35	$20	$7
Power:	kWh	1679	$0.04	$67
Maintenance supplies	$/day	-	-	$100
Assays	$/day	-	-	$30
Labour:				
1 Supervisor/Engineer @ 4 hrs/wk x $50/h	$/day			$29
1 Operator @ 28 hrs/wk x $13/hr	$/day	-	-	$52
1 Mech./Elect.@ 10 hrs/wk x $26/h	$/day	-	-	$37
TOTAL DAILY EXPENSES				**$2,254**
REVENUES				
Copper Product:				
41kg/day @ $2.48/kg x 70% NSR	$/day	-	-	$71
Zinc Product:				
812 kg/day @ $1.82/kg x 60% NSR	$/day	-	-	$887
NaHS Product				
1.0 tonnes/day @ $1050/tonne	$/day	-	-	$1,050
GROSS DAILY REVENUE				**$2,008**

NET ANNUAL REVENUE (LOSS)	**($89,977)**
NET ANNUAL LIME SAVINGS	**$435,000**
NET ANNUAL SLUDGE SAVINGS	**$0.00**
NET ANNUAL PROFIT (COST)	**$345,023**

Caribou Mine - Expanded Case 2100 m3/d AMD plus 210 tpd Anaconda Tailings - Option 2b
ESTIMATE OF COMMERCIAL PLANT OPERATING COSTS/REVENUES

Item	Units	Units/day	$/Unit	Total $/day ($CDN)
EXPENSES				
Diesel fuel	L	14509	$0.29	$4,208
KH2PO4 nutrient	kg	116	$0.28	$32
(NH_4)SO4 nutrient	kg	1156	$0.41	$474
Flocculant	kg	31.5	$4.30	$135
Caustic (NaOH) @115% stoichiometric	tonnes	2.47	$495	$1,223
Sulphuric acid	tonnes	10.9	$50	$545
Limestone	tonnes	1.7	$21	$36
Gypsum	tonnes	6.0	$20	$120
Power:	kWh	1679	$0.04	$67
Maintenance supplies	$/day	-	-	$100
Assays	$/day	-	-	$30
Labour:				
1 Supervisor/Engineer @ 4 hrs/wk x $50/h	$/day			$29
1 Operator @ 28 hrs/wk x $13/hr	$/day	-	-	$52
1 Mech./Elect.@ 10 hrs/wk x $26/h	$/day	-	-	$37
TOTAL DAILY EXPENSES				**$7,051**
REVENUES				
Copper Product:				
1,300 kg/day @ $2.48/kg x 70% NSR	$/day	-	-	$2,257
Zinc Product:				
4,000 kg/day @ $1.82/kg x 60% NSR	$/day	-	-	$4,368
NaHS Product				
3.0 tonnes/day @ $1050/tonne	$/day	-	-	$3,150
GROSS DAILY REVENUE				**$9,775**

NET ANNUAL REVENUE (LOSS)	**$994,092**
NET ANNUAL LIME SAVINGS	**$435,000**
NET ANNUAL SLUDGE SAVINGS	**$0.00**
NET ANNUAL PROFIT (COST)	**$1,429,092**

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Based on the laboratory data available and the analysis provided in this study, the salient conclusions are:

- The process Option 2b, treatment of 2,100 m^3/d AMD and concurrent re-treatment of 210 tonnes per day Anaconda Tailings, results in a project with a capital payback of approximately 3 years, re-treatment of all of the Anaconda Tailings and overlying sludge in slightly more than 5 years, and a treatment plant that is moderately over-sized for ongoing treatment of 2,100 m^3 per day AMD.
- Utilization of the BioSulphide Process would provide a long term treatment alternative for AMD neutralization that would show a slight profit annually, at current metal prices and including a credit for lime savings. The ongoing sludge produced would have copper, zinc, lead and cadmium removed and can probably be stored in the tailings pond, reducing sludge liability long term.
- The total capital cost, for new equipment and independent contractors for construction was estimated at $Cdn 3.4 million for Option 2b.

7.2 Financial Analysis

The estimates provide for Options 2a and 2b indicate that there is positive project economics in the short term to reclaim and re-treat Anaconda Tailings for metal recovery and tailings disposal and in the long term for ongoing AMD treatment.

The project is particularly sensitive to fuel costs, which is directly related to the overall hydrogen utilization from the partial oxidation burner and in the bioreactor. The overall hydrogen utilization value of 60% is reasonable based on current burner and pilot information. Also, the project is very sensitive to diesel fuel price.

The metal pricing and NSR estimates for the concentrate products used in the operating cost/revenue estimates are reasonable based on current markets. The project is sensitive to metal pricing and concentrate grade and related smelter terms.

Upside Potential

There is significant upside potential in the project if oxidized tailings are included in the leach circuit estimates. The data provided by RPC, Appendix 1, suggests that a significant portion of the Anaconda Tailings have been oxidized, which will result in an increase in the recoverable metals, thus an increase in revenues, particularly from copper.

There is significant cobalt content in the hydroxide sludge overlaying the tailings. It might be possible to selectively recover this cobalt to a saleable end product, increasing revenues.

The neutralizing potential and residual sulphate content of the hydroxide sludge has not been incorporated in the analysis. There is potential for savings in limestone and gypsum once confirmatory data on sludge quality is available.

7.3 Recommendations

Based on the results of the laboratory work todate and the results of the prefeasibility estimates it is recommended that:

- A mini-pilot plant is operated at site to confirm the BioSulphide operating criteria, to assist with pilot scale design and provide sufficient sample of concentrate and leach residue product for downstream process studies.
- Additional leaching studies are completed to incorporate areas of the stored tailings where advanced oxidation is evident and areas including overlaying sludge, to provide a better estimate of overall metallurgical balance and iron deportment.
- Comparative stability testing is conducted on the Anaconda tailings, acid leached tailings and existing mill tailings.
- Confirmation of the AMD flow and grade for the 2,100 m^3/d flowrate.

APPENDIX 1

Results of Site Due Diligence Visit

CARIBOU MINE
A division of CanZinco Ltd.

Memorandum

DATE: **September 22, 1999**

A / TO: **Brad Marchant, Biomet**

DE / FROM: **Bob Carreau**

CC:

RE: **Due Diligence**

1.0 Production

1. Property Water Balance:
   - Withdraw approximately 16,350 m^3/d of reclaim water from Tailings Pond for mineral processing
   - Discharge approximately 17,075 m^3/d of water to Tailings Pond (takes into consideration 50 m^3/d water loss to concentrates and 775 m^3/d inflow from mine water drainage)
   - Consume approximately 150 m^3/d of potable water from Caribou Lake for hygiene and lab purposes – discharge to septic field
   - No other site drainage collected

2. AMD Flow and Grade:
   - See attached files ("caribou ug pump.xls" and "caribou metals ug.xls". These show seasonal fluctuations and water quality.

   700 m^3/d.

3. OH Sludge quantity:
   - Storage area is approx. 70 m x 40 m x 6 m deep. Estimate approx. 15,000 cubic metres of reclaimable material.

4. Anaconda Ponds:
   - Best available data is from 1995 RPC report (you have a copy).

5. Discharge criteria:
   - Our site discharge criteria (during operations or shutdown) is based on the MMLER for Cu, Pb and Zn (0.3, 0.2 and 0.5 mg/L respectively). We have no regulated criteria for Mn, Al and Fe other than they must not be in sufficient concentration to cause the site discharge to fail monthly Acute Lethality tests.

The major consideration in determining the discharge quality from your process (or the Anaconda leach process) is that your discharge stream would enter the 3.6 million cubic metre tailings pond (maintained at 8.5 pH) prior to discharge to the receiving stream. Therefore it is conceivable that a somewhat higher discharge criteria could be endured without affecting the site discharge quality. Perhaps as a starter we could: 1) work toward meeting the MMLER criteria for Cu, Pb and Zn; and 2) see what we get for Al, Mn and Fe and test for Acute lethality.

6. Dilution in receiving water:
    - I have attached a file (tailings pond.xls) which shows water chemisty and discharge flows from our tailings pond (where the biomet discharge stream will report). As stated above, the tailings pond has a volume of 3.6 million cubic metres and a surface area of 90 hectares.

2.0 Consumables

1. Diesel Fuel:
    - Irving Oil (Bathurst)
    - Contracted pre-tax price of $0.29/L
2. Electrical power:
    - $0.04 (during operation)
3. Lime:
    - Hydrated
    - Havelock, NB
    - Delivered at $128/tonne
4. Flocculant:
    - Percol 351
    - Allied Colloids
    - $4.30/kg

3.0 Labour

1. Labour Rate:
    - $13/hr

Project: Tailing treatment of Caribou Mine Site

Subject: Reserve and Tailing Mtal Value Estimates

Location Pond/Hole	Depth	Area	Volume	Percent Water	Tails Volume	S.G	Weight	Weight	Total Cu	Cu as Oxide	Total Pb	Pb as Oxide	Total Zn	Zn as Oxide	Ag	Au	Fe
	(m)	(m2)	(m3)	(%)	(m3)		(Tonnes)	(Tons)	(%)	(%)	(%)	(%)	(%)	(%)	(oz/t)	(oz/t)	(%)
A-1	3.20	3280	9510	30	6655	2.72	18102		1.45	0.46	2.77	2.02	3.45	1.34	2.19	0.028	26.52
A-2	7.01	3180	21033	30	14725	2.72	40052		1.62	0.07	1.98	1.11	3.08	0.17	2.01	0.026	30.23
A-3	4.42	1530	5977	15	5080	2.72	13818		2.07	0.29	1.48	0.73	2.78	0.16	1.90	0.024	35.56
A-4	4.42	1280	4860	10	4375	2.72	11900		2.43	0.45	1.09	0.52	2.56	0.11	1.81	0.031	36.90
A-5	6.25	2270	8538	15	7255	2.72	19734		2.35	0.22	0.95	0.60	2.80	0.14	1.83	0.031	36.12
A-6	8.38	1580	11851	50	5925	2.72	16116		2.94	0.28	2.06	1.38	3.37	0.20	2.71	0.027	33.36
A-7	12.80	2465	19239	50	9620	2.72	26166		1.63	0.12	2.26	1.41	2.97	0.25	2.00	0.020	29.88
A-8	11.58	2130	18212	50	9105	2.72	24766		1.88	0.10	2.15	1.39	3.00	0.21	2.27	0.022	29.87
A-9	11.28	1400	14772	50	7385	2.72	20087		1.92	0.07	2.04	1.36	3.02	0.16	2.54	0.023	29.86
A-10	9.45	1240	10613	45	5835	2.72	15871		2.25	0.21	1.50	0.91	2.71	0.17	2.12	0.030	33.68
Average	6.20	20375	126605	40	75960	2.72	206612	227751	1.99	0.19	1.90	1.18	3.00	0.28	2.13	0.026	31.59

Location Pond/Hole	Depth (m)	Area (m2)	Volume (m3)	Percent Water (%)	Tails Volume (m3)	S.G	Weight (Tonnes)	Weight (Tons)	Total Cu (%)	Cu as Oxide (%)	Total Pb (%)	Pb as Oxide (%)	Total Zn (%)	Zn as Oxide (%)	Ag (oz/t)	Au (oz/t)	Fe (%)
B-1	2.90	1860	3910	20	3130	2.5	7575		1.57	1.16	0.12	0.07	2.21	1.53	0.44	0.023	16.20
B-2	4.88	1460	6680	30	4675	2.7	12663		1.53	1.04	0.16	0.09	2.86	1.88	0.49	0.019	20.24
B-3	7.47	1740	10409	40	6245	2.3	14364		1.89	1.87	0.29	0.16	4.70	3.56	0.46	0.011	12.38
B-4	9.30	1820	10650	40	6390	2.3	14697		1.79	1.48	0.58	0.30	4.75	3.30	0.78	0.013	12.54
B-5	8.23	1727	10997	40	6600	2.2	14520		1.30	1.30	0.59	0.43	5.02	3.16	0.66	0.010	10.27
B-6	5.79	1610	7926	40	4755	2.6	12363		1.50	1.22	0.20	0.12	3.27	2.30	0.56	0.014	18.76
B-7	2.13	1310	2486	40	1490	2.7	4023		1.58	1.26	0.18	0.10	4.69	3.39	0.53	0.022	17.75
Average	4.60	11527	53058	37	33285	2.4	80205	88411	1.60	1.37	0.34	0.21	4.02	2.78	0.58	0.015	14.88
M1-1	1.83	710	1073	10	965	2.72	2625		3.96	0.52	0.37	0.12	3.15	0.30	1.86	0.038	30.47
M1-2	1.37	730	974	10	875	2.72	2380		3.40	0.45	0.44	0.04	1.90	0.11	1.97	0.046	31.55
M1-3	0.97	580	451	10	4[illegible]	2.72	1102		1.64	0.27	0.40	0.02	0.47	0.04	1.59	0.045	31.45
Average	1.24	2020	2498	10	2245	2.72	6107	6732	3.32	0.45	0.40	0.07	2.18	0.18	1.85	0.042	31.07
M2-1	1.07	390	315	10	285	2.4	684		0.53	0.46	0.15	0.06	0.36	0.26	0.41	0.012	14.44
M2-2	1.07	530	523	10	470	2.6	1222		0.75	0.40	0.12	0.02	0.41	0.28	0.58	0.017	19.41
M2-3	1.37	480	526	10	475	2.7	1283		1.04	0.28	0.14	0.03	0.36	0.17	0.93	0.020	21.64
Average	0.96	1400	1344	10	1230	2.59	3189	3515	0.81	0.36	0.13	0.03	0.38	0.23	0.67	0.017	19.08
Totals:	5.2	35322	183505	39	112720	2.63	296113	326409	1.90	0.52	1.43	0.88	3.23	0.95	1.69	0.023	26.92

AGRICULTURAL GYPSUM

SPECIFICATION SHEET

GOOD STUFF GYPSUM

15.80 US$/t
F.O.B. mine

	TYPICAL LAB ANALYSIS	MINIMUM GUARANTEE
Calcium Sulfate (CaSO 2H 0)	107.5%	100.00%
Calcium (Ca)	25.2%	23.28%
Sulfur (S)	20.0%	18.62%

LAB PROCEDURE

Guaranteed minimum analysis is based on the short method used by the State of California and other Western states.

MOISTURE:	5 to 12%
BULK DENSITY:	1.40
HARDNESS:	3 to 3.5
LBS PER CU FT:	87.36
LBS PER CU YD:	2,358.72
PH:	7.03
PARTICLE SIZE:	4 mesh minus
CRYSTAL SYSTEM:	Orthorhombic

SCREEN ANALYSIS

SCREENS	PERCENT
+4 Mesh	1.9
+6 Mesh	7.7
+8 Mesh	6.9
+20 Mesh	18.4
+50 Mesh	19.8
+100 Mesh	17.1
+150 Mesh	6.3
+200 Mesh	4.7
+325 Mesh	7.6
−325 Mesh	9.6

$ VALUE OF HIGH GRADE GYPSUM

High purity gypsum delivers a greater dollar value & savings to the farmer. The active ingredient in gypsum is calcium sulfate. In lower grade gypsum other elements beyond the minimum guarantee, such as silica, are of no value to the crop. Use this simple formula to determine how much you are paying for the actual amount of calcium sulfate you get instead of just fillers. You should get what you pay for. Let's say, for example, that a delivered price of $40 is the same for our 100% gypsum as it is for a lower grade of 70% gypsum.

The following is what you are paying per ton of 100% calcium sulfate:

$40 : 100% = $40.00
$40 : 70% = $57.14

This is a savings of $17.14 per ton, or $428.50 per load.

SOURCE

Good Stuff Gypsum is a white, natural, earth mineral from deposits of dihydrate and anhydrite gypsum in Nevada, and contains no harmful impurities.

John Mahan, Director of Marketing
P.O. Box 1160, Carson City, NV 89702
Phone: (775) 882–0700
Fax: (775) 882–0790

olsym22\gypspec

Chemical and Agricultural
Limestone Products

Produits de Chaux
Chimique et Agricole

Elmtree Resources

Brad Marchant
Biomet Mining Corporation
Unit 360 – 3771 Jacombs Road
Richmond, BC
V6V 29L

September 24, 1999

Subject: Limestone Pricing

Brad:

We have an assortment of product sizes and grades, however, I suspect you require a finely crushed material with a high mesh number. We can provide the following:

Agricultural Limestone
45% passing 100 mesh
100% passing 16 mesh
2 – 3 % moisture

Minimum Grade:
92% $CaCO_3$
0.6% MgO
6.0 % SiO_2

We can provide you with the following:

Product Pricing:	$ 16.00 CAD/tonne
Transportation:	$ 5.40 CAD/tonne (Summer Rate – June - October)
	$ 11.15 CAD/tonne (Winter Rate)

Please note that the summer transportation rate allows us to ship directly from our plant facility to the Caribou mine site on a road maintained only during the summer months. The increased haulage rates in winter pertain to the additional transportation costs associated with using a longer route and utilizing our winter storage facility that is not convenient to the Caribou mine site. If you had capacity to store 1000 tonnes on site for the winter months, we could ship the entire amount during the summer at the lower rate.

We could also attempt to cover a small 1000 tonne stockpile at our plant site for use in the winter. If successful, you could reduce the winter rate by 3.00/tonne.

The transportation rate assumes a minimum shipment size of 30 tonnes delivered approximately once/week.

I trust this information is as you requested. If you need anything further, please do not hesitate to call.

Regards,
Michael Buzas

Elmtree Resources Ltd., 1370 Johnson Ave, Bathurst, NB, E2A-3T7
Tel: 506-546-6382, Fax: 506-548-3137, Email: erl@nbnet.nb.ca

Van Waters & Rogers Ltd.
A ROYAL PAKHOED COMPANY

32 MOSHER DRIVE
DARTMOUTH, NOVA SCOTIA
B3B 1E6
PHONE: (902) 468-5413
TELEFAX: (902) 468-3870

September 22, 1999

Biomet Mining
(Caribou Mine)
Unit 360
3771 Jacombs Road
Richmond, BC
V6V 2L9

ATTENTION: Mr. Brad Marchand

Subject: Quotation

Dear Brad:

We are pleased to quote on the following product:

CAUSTIC SODA 50% SOLUTION

Code:	18-14895
Pkg Weight & Type:	Bulk
Price:	$0.40/kg dry solution CDN, FOB St. John, NB
Total Quantity:	To be confirmed
Minimum Order Quantity:	20,000 kgs

TERMS & CONDITIONS:

Price Protection:	Prices firm until December 31, 1999.
Lead Time:	2-3 days
Taxes:	Extra, if applicable
Terms:	Net 30 days

Code: SAS93-06
Page 1 of 1

Noranda-Dupont LLC

93% Fertilizer Grade
Sulphuric Acid Specifications

Property	Units	Specification
H_2SO_4	%	92.5 min
	%	94.5 max
SO_2	ppm	80 max
Nitrates as NO_3	ppm	20 max
Iron (Fe)	ppm	100 max
Zinc (Zn)	ppm	10 max
Mercury (Hg)	ppm	3 max
Copper (Cu)	ppm	5 max
Lead (Pb)	ppm	3 max
Nickel (Ni)	ppm	5 max
Chromium (Cr)	ppm	5 max
Cadmium (Cd)	ppm	5 max
Chlorides (Cl)	ppm	10 ppm
Arsenic (As)	ppm	5 max
Manganese (Mn)	ppm	5 max
Selenium (Se)	ppm	10 max
Clarity @ 500 nm	%	30 min

Revision: 02
1997-01-13

Signature and Title

Company Name

Date

noranda DUPONT

Noranda DuPont of Canada Inc

Joseph A Plut

Noranda DuPont of Canada Inc.
PO Box 61 Streetsville
Mississauga, Ontario
L5M – 2B7
Phone: 905-821-5819
FAX: 905-821-5876
E-mail: plutj@normin.com
www.sulfuricacid.com

FAX

To: Brad Marchant Biomet Mining Corp. 604 276 8601

Copy: Geoff Cowell

Date: November 24, 1999

SUBJECT: **Sulphuric Acid to Caribou Mine Site, NB**

Brad, as per our conversation this is to confirm a price of $55.00/tonne for sulphuric acid delivered to your facility at the Caribou Mine site. This price, as discussed, is for feasibility study purposes only and is subject to further discussion that would include delivery terms, quality requirements, volume and payment terms.

Thanks for allowing Noranda Dupont the opportunity to quote on your business.

Please call me if you have any further questions.

Regards,

Joe.

Joseph A Plut